AFQTP 3E0X1-18
1 OCT 99

AIR FORCE

QUALIFICATION TRAINING PACKAGE (AFQTP)

for

ELECTRICAL SYSTEMS

(3E0X1)

MODULE 18

DISTRIBUTION SYSTEMS, 600 VOLTS AND LESS

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REVIEW ANSWER KEY .... Key 1

Career Field Education and Training Plan (CFETP) references from 1 Apr 97 version.

OPR: HQ AFCESA/CEOF Certified by: HQ
AFCESA/CEO
(SMSgt Mike Trevino) (Colonel Lance C. Brendel)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

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ELECTRICAL SYSTEMS
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INTRODUCTION

Before starting this AFQTP, refer to and read the "Trainee/Trainer Guide" located on the AFCESA Web site **http://www.afcesa.af.mil/.** This guide will be found at each AFS's AFQTP download page.

AFQTPs are mandatory and must be completed to fulfill task knowledge requirements on core and diamond tasks for upgrade training. ***It is important for the trainer and trainee to understand*** that an AFQTP ***does not*** replace hands-on training, nor will completion of an AFQTP meet the requirement for core task certification. AFQTPs will be used in conjunction with applicable technical references and hands-on training.

AFQTPs and Certification and Testing (CerTest) must be used as minimum upgrade requirements for Diamond tasks.

MANDATORY minimum upgrade requirements:

Core task:

AFQTP completion
Hands-on certification

Diamond task:

AFQTP completion
CerTest completion (80% minimum to pass)

Note: *Trainees will receive hands-on certification training when equipment becomes available either at home station or at a TDY location.*

Put this package to use. Subject matter experts under the direction and guidance of HQ AFCESA/CEOF revised this AFQTP. If you have any recommendations for improving this document, please contact the Electrical Career Field Manager at the address below.

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INSTALL

MODULE 18 AFQTP UNIT 1

SERVICE-ENTRANCE (18.1.1.)

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SERVICE-ENTRANCE

Task Training Guide

STS Reference Number/Title:	18.1.1. Distribution systems, 600 volts and less, install service-entrance
Training References:	• CDC 3E051A, Vol. 4 • Most current National Electrical Code
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool box • Rigid conduit threader
Learning Objective:	• Given equipment, install a service-entrance
Samples of Behavior:	• Follow the required steps to install a service-entrance • Know safety requirements associated with installing a service-entrance
Notes:	
• Any safety violation is an automatic failure.	

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SERVICE-ENTRANCE

Background: The overhead service-entrance brings power from the service drop to the service disconnecting means of a building. The disconnecting means include panelboards and safety switches with the service entrance ending on their line side lugs. If an underground service is used, the service-entrance starts at the terminal box or meter base and ends at the service disconnecting means.

NOTE:
If the underground service does not use a terminal box or meter base, and is installed directly into the main disconnect from the power source, then it will depend on local guidance to determine if a service-entrance exists and where it starts.

Naturally, one of the components of the service-entrance is the conductor through which the current flows. This conductor may consist of individual wires that run through the raceway, such as rigid metal conduit, electrical metallic tubing, or rigid nonmetallic conduit. The raceway provides the conductors with protection from physical and weather damage.

NOTE:
Power may also be brought into a building with a service-entrance (SE) cable. This cable does not need raceway protection unless it is likely to be damaged physically by abrasion or from being struck by passing equipment.

The grounded conductor is not normally switched. When it is, the switch must be in the form of a circuit breaker and all the ungrounded conductors must open simultaneously with the grounded conductor. Regardless of whether it is switched, the grounded conductor has to be fixed so it can be disconnected. A terminal or bus bar to which all grounded conductors can be attached by means of pressure connectors meets this requirement. The service-entrance must be grounded to a low-resistance ground.

A service head, also called a weathered (Figure 1), is used with a raceway to provide an entrance for the conductors into the raceway. The service head prevents the entrance of rain into the raceway. The conductor holes in the service head are bushed to reduce abrasion on the insulation. A service head can also be used on SE cable or the cable can be formed into a gooseneck (Figure 2) to keep rain out. When a gooseneck is used, the gooseneck is taped self-sealing, weather-resistant thermoplastic.

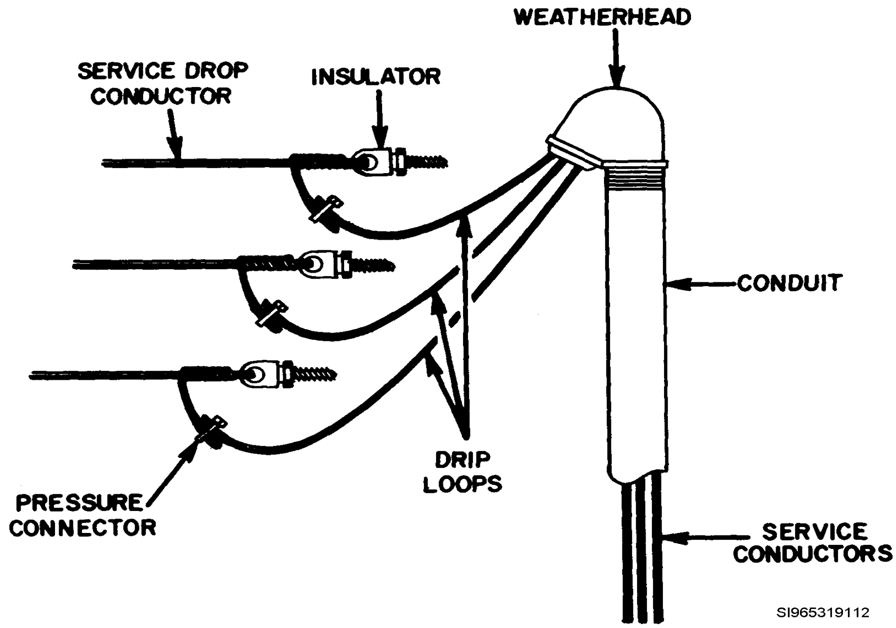

Figure 1, Weatherhead

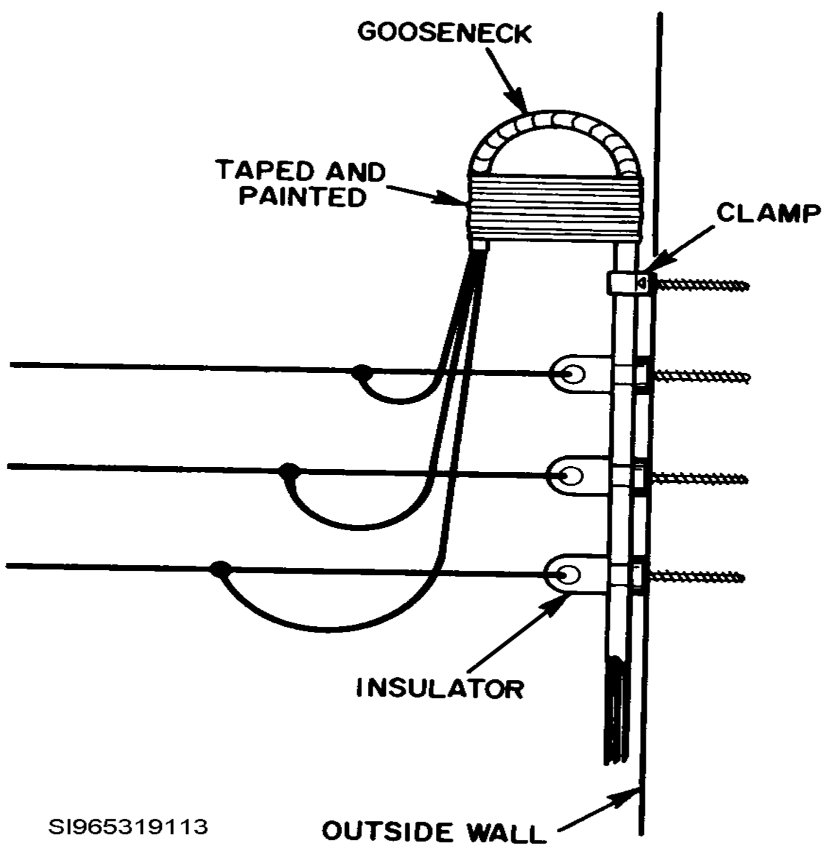

Figure 2, Service-Entrance Cable Gooseneck

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Power delivered to the building may need to be measured to determine how much is used. When this is necessary, a meter socket is installed in the service-entrance (SE) conductors so that a wattmeter may be included to record power consumption. This is the only piece of service equipment that is mounted in line ahead of the service disconnect.

The service entrance must have a means of disconnecting the power supply from the interior building circuits. A service disconnect or main switch turns off all interior power in case of a fire or other emergency condition. It may be mounted inside the building or outside on the exterior wall. In addition to overload protection, it is also useful when work is to be performed on the panelboard or several circuits at the same time. Although the service-entrance connects to the line side lugs and neutral lug or bus bar, the disconnect is considered a part of the service equipment.

Determine the type and size of Service.

- Type of service is a factor to be considered. Determine what voltage and number of phases will be needed. Single-phase power is usually supplied for residential applications while three-phase power is normally used in commercial and industrial locations.
- Whether the service is going to be overhead or underground and raintight or interior mounted are also key factors.
- The planned and anticipated electrical load in the building determines the size and number of conductors. This load is based on the need for lighting and small appliances, plus the power to operate heavier equipment, such as dryers, furnaces, and motor-driven equipment.
- There are also some minimum size requirements for conductors. For instance, the service drop conductors can be either copper or aluminum. Copper service drop conductors must be no smaller than No. 8 AWG. A single-family dwelling requires a three-wire service entrance of at least 100-ampere capacity.
- Service-entrance conductors are usually larger than service drop conductors. This is due to increased amperage rating permitted for service drop conductors in free air. Free air dissipates heat quicker than air confined in a raceway. Information concerning permissible methods of protecting Service entrance conductors is found in the *NEC*®.

To install the Service Mast (Overhead in Conduit).

- The service entrance conductors may be brought in through rigid metal conduit. This conduit may be installed as a service mast or as just metal conduit. The mast is made from a single length of rigid steel conduit with a minimum recommended diameter of 2 inches. The size and number of conductors being used determine the diameter of the mast. The appropriate sizes can be found in the *NEC*®.
- Install through the roof and go down inside the wall between the studs. The mast must be strong enough to provide an anchor for the service drop.
- When the drop is anchored to the mast, it may be as close as 18 inches to the roof as long as it does not pass over more than 4 feet of roof overhang. If the mast is not strong enough as installed, braces or guys are added to provide the necessary support.
- A roof flashing plate with a neoprene seal is installed over the mast where it comes through the roof to prevent water leakage.
- Attach a weatherhead to the top of the mast.
- At the bottom of the mast, fittings are installed to permit mounting of the meter socket and the service disconnect, or just the disconnect if power is not to be metered.
- The service mast may be installed so that it comes down the exterior wall of the building. It is anchored to the wall with pipe support clamps that are held in place by bolts extending through the wall. In many cases, screws driven into the siding or some type of screw

anchor provide adequate support for the pipe clamps. This method of mounting a service mast still requires the use of a roof flashing plate and neoprene seal to prevent water leakage.

- The service conductors may also be brought in through rigid metal conduit fitted with a weatherhead and fastened to the building wall but not extending through the roof.

To install Service-Entrance (SE) Cable.

- The SE cable can be used for the service entrance in place of rigid conduit where it is not apt to be damaged physically. The SE cable has the insulated conductors wrapped with the stranded neutral conductor. This method of wrapping the neutral around the other conductors provides some protection from damage and gives some added stiffness.
- Attach a weatherhead at the service drop end of the SE cable to protect against moisture. Another means of keeping moisture out is to form a gooseneck on the end of the SE cable as shown in Figure 2. This gooseneck must be taped with a self-sealing, weather-resistant thermoplastic.
- Support the SE cable by a cable clamp within 12 inches of the weather head, gooseneck, or connection to a raceway. Additional clamps are required for support at intervals no more than 4 feet apart.
- The service cable enters the interior of the building through a hole drilled in the exterior wall. A hole is easily bored in a wooden wall either by hand or with a powered drill. A masonry drill or star drill must be used on masonry walls.
- The hole size is dictated by the size of the entrance cable.

> **NOTE:**
> The hole should permit the cable to enter without damage but should not be large enough to cause sealing problems. Additional space is required in cases where the grounding electrode conductor comes out through the SE cable entry hole.

- After you insert the entry cable through the wall, screw a wallplate with either a soft rubber gasket or non-hardening sealing compound to the wall. This plate holds the SE cable in place and provides a weatherproof seal.

To install Underground Service-Entrance Systems.

- Electrical power may be brought into a building from underground instead of overhead. In fact, underground distribution is becoming more and more common. In a few cases, the distribution system is overhead but the building service is underground.
- The conductors, which correspond to the service drop and bring power to the building, are called the service laterals. These conductors may be tied to an overhead distribution system and then run down the pole into the ground before they are run to the building. In other cases the entire distribution system, except for the transformers, is underground.
- The service lateral may be connected to an underground secondary main; or, if separate transformers serve the building, it is connected to the transformers.
- The service lateral may be installed in rigid conduit (either metallic or nonmetallic) or it can be installed with underground service entrance (USE) cable.
- In Figure 3, you see the layout of an underground service to a building. In this illustration, the service lateral runs from the transformer to the terminal box.

> **NOTE:**
> A terminal box is installed whenever a meter is to be part of the system, the wiring method is changed (e.g., from conduit to cable), or multiple disconnects are to be used.

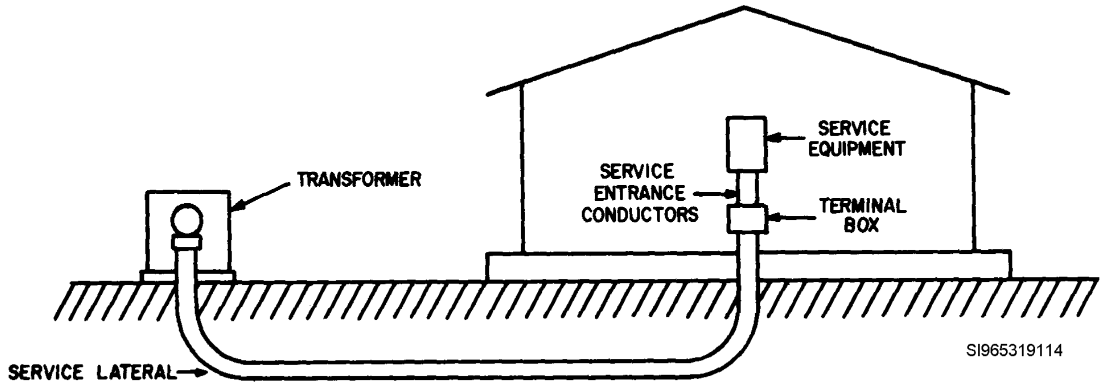

Figure 3, Underground Service to Building.

- Whenever the service lateral is connected directly to the service equipment (disconnect), the point of connection between the service lateral and the service entrance is the point of entry to the building. The service lateral can be installed outside the building and will terminate in either a terminal box or the service equipment.
- There are no SE conductors if the service lateral connects directly to the service equipment outside the building.
- Underground service laterals must be protected from damage by meeting minimum burial depths. Underground service entrance cable and other direct-burial cable must be buried at least 24 inches deep. Rigid metal conduit needs to be only 6 inches deep, but rigid nonmetallic conduit approved for direct burial must be 18 inches deep. USE cable entering a building from underground must be protected by an approved entrance or raceway from the point of entrance to below the ground line, and beyond the outside walls of the building. The maximum depth for required use of raceway for protection of USE cable is 18" below grade and a minimum 8' above grade. The rest of an underground service entrance is the same for an overhead system.

To install Service Conductors.

- The service conductors are insulated wires that run in one continuous length from the service drop to the service disconnect.

> **NOTE:**
> The 1999 National Electrical Code article 230-46 allows splices.

- The neutral conductor may be a bare wire when the service conductors are enclosed in a raceway.
- Where a meter is included as part of the service entrance, the conductors are run from the service drop to the meter socket. A second set of conductors connects the meter socket to the service disconnect. Figure 4 shows how the service conductors are wired to a meter mount.
- The weatherhead (or service head) should be higher than the point where the service drop is anchored. When this is not possible, the weather head may be placed to the side of, or even below, but not more than 24 inches from the service drop.

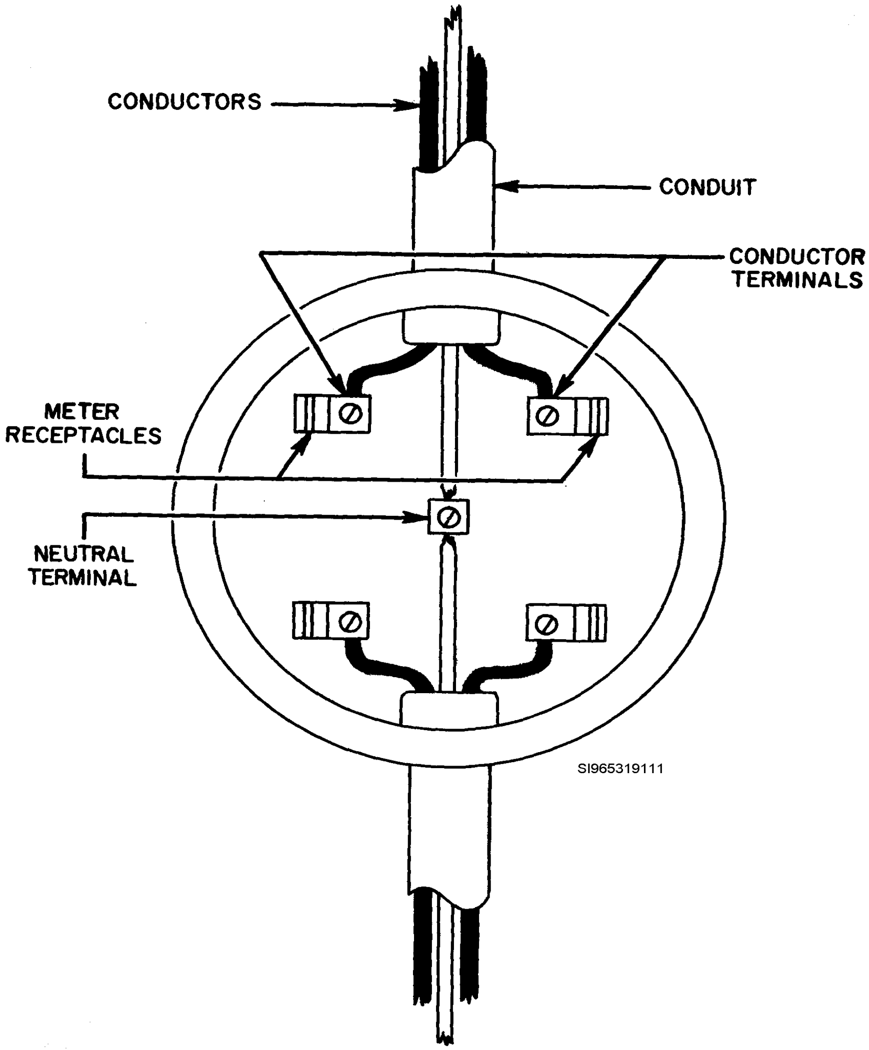

Figure 4, Service Entrance Connections

- The service conductors that enter the service disconnect must be long enough to connect easily with the switch terminals. The neutral conductor is usually longer since it connects to the neutral bus bar.
- Terminal lugs are needed on the conductors because of their large size. These are attached by pressure rather than by solder because large solder connections are difficult to make.
- Make the service conductors long enough to provide drip loops between where they are connected to the service drop and the weatherhead, as shown in Figure 4. These drip loops prevent water from running down the service conductors into the weatherhead when it rains.
- Splice the service conductors to the service drop conductors with split bolts or other types of pressure connectors, starting with the neutral conductor.

- If the service drop conductors are aluminum, special connectors are needed to prevent electrolytic corrosion from taking place between the aluminum and the copper service conductors.

NOTE:
Be sure to get the aluminum conductor in the proper space in these connectors.

- Tape the connectors and wire ends on the insulated conductors after the splice is complete. You do not need to tape the neutral if it is a bare wire.

SAFETY:
REMOVE ALL JEWELRY BEFORE BEGINNING ANY WORK. WHEN CONNECTING THE SERVICE ENTRANCE TO THE SERVICE DROP ENSURE THE LINES ARE DE-ENERGIZED.

Service Entrance installation categories with associated steps.

Instructions: Although there are many variations and applications that are unique to the situation, below are listed two common types that are generally used. In all cases, the most current edition of the NEC should be used to ensure all code requirements and exceptions are met.

A. Using most current NEC, determine type and size of service required for overhead entrance using a weatherhead and external disconnect.

- Phasing and amperage requirements will be used to determine number of conductors as well as raceway, panel, wire and fuse sizing.

SAFETY NOTE: Always check and verify power is disconnected prior to working around service drop.

Step 1: Install service mast.

- Cut raceway to proper length, clean and thread.
- Attach raceway to disconnect.
- Secure raceway to structure.
- Place grounding bushing on end of raceway except if a hub is used.

Note: Disconnect installation covered in Service Equipment module 18.1.2

Note: Although most facilities on an Air Force base do not have a wattmeter, if one is to be installed, the service mast would connect to it and a raceway would connect the wattmeter to the disconnect.

Step 2: Install wires in service mast.

- Ensure proper wire type, size and insulation.
- Without cuts, gouges, or excessive bending.
- Enough extra wire should be left hanging out on both ends to allow for drip loops and/or connections.

Step 3: Install weatherhead at the top of the raceway.

- Pull wires through weatherhead.
- Pull wires through individual holes in weatherhead bushing.
- Tightly secure weatherhead and bushing in place.

Step 4: Connect conductors to disconnect.

- Properly strip and secure neutral wire to neutral bus bar or lug..
- Properly connect current carrying conductors to Line side.

> **Note:** Grounding electrode installation covered in System and Equipment Grounds module 18.1.3.

Step 5: Connect conductors to Service drop.

- Form individual drip loops to hang below the level of the weatherhead
- Properly strip and secure neutral wire to service drop.
- Properly strip and secure current carrying conductors to service drop.
- Tape connections.

B. Using most current NEC, determine type and size of service required for overhead entrance using service entrance cable and gooseneck with an interior disconnect.

- Phasing and amperage requirements will be used to determine amount of conductors as well as raceway, panel, wire and fuse sizing.

> **SAFETY NOTE:** Always check and verify power is disconnected prior to working around service drop.

Step 1: Install cable to service disconnect.

- Ensure proper wire type, size and insulation.
- Drill hole through exterior wall to disconnect.
- Ensure wire is free of cuts, gouges or excessive bending.
- Cut cable to proper length.
- Install cable through hole and into disconnect.
  - Enough extra wire should be left hanging out on both ends to allow for drip loops and/or connections.
- Strap cable to support.
- Seal hole in wall.

- Screw a wallplate with soft rubber gasket or non-hardening sealing compound to the wall.

Note: Disconnect installation covered in Service Equipment module 18.1.2

Step 3: Install gooseneck on cable.

- Tape top of cable (other end from disconnect).
- Enough excess wire should be left at the end and untaped to form drip loops and connections.
- Form gooseneck.
  - Securely tape in place.
  - Overlap tape layers as you go up cable.

Note: Self-sealing weather resistant thermoplastic tape must be used. Painting is optional.

Step 4: Connect conductors to disconnect.

- Properly strip and secure neutral wire to neutral bus bar or lug.
- Properly strip and secure current carrying conductors to Line side lugs.

Note: Grounding electrode installation covered in System and Equipment Grounds module 18.1.3.

Step 6: Connect conductors to Service drop.

- Form individual drip loops to hang below the level of the gooseneck.
- Properly strip and secure neutral wire to service drop.
- Properly strip and secure current carrying conductors to service drop.
- Tape connections.

Review Questions
for
Service-Entrance

Question	Answer
1. What is the purpose of the overhead service-entrance system?	a. To provide a grounding point for service conductors. b. To bring power from the service drop to a panel in the building. c. Provide overcurrent protection. d. All of the above
2. What does the raceway protect the service conductors from?	a. Physical damage b. Weather damage c. Both a and b d. None of the above
3. The service head prevents the entrance of _____ into the raceway.	a. Conductors b. Rodents c. Stray currents d. Rain
4. When using SE cable, water can be kept out by the use of a service head or by a ____.	a. Gooseneck. b. Service mast. c. Service entrance. d. Meter socket.
5. The service entrance ends at the service mast.	a. True b. False
6. The first requirement for installation of the service entrance is to determine size and ____ of the conductors.	a. Color b. Amperage c. Diameter d. Type
7. How does the size of service entrance conductors compare to the size of service drop conductors?	a. Entrance conductors are the same size b. Entrance conductors are smaller size c. Entrance conductors are larger size
8. What is the only piece of service equipment that is mounted in line ahead of the service disconnect. .	a. Insulator b. Wattmeter c. Service head d. Safety switch
9. What seals a hole around SE cable entering an exterior wall?	a. Rubber gasket b. Hardened sealer c. Quickcrete d. Metal plate
10. Some underground services do not have a service-entrance.	a. True b. False

SERVICE ENTRANCE

Performance Checklist		
Step	**Yes**	**No**
1. Did the trainee determine the wire size and type required?		
2. Did the trainee ensure power was off prior to starting work?		
3. Did the trainee install the service mast, SE cable or service lateral?		
4. Did the trainee install the service conductors?		
5. Did the trainee install the weatherhead or gooseneck?		
6. Did the trainee connect the conductors to the disconnect?		
7. Did the trainee connect the conductors to the service drop?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

INSTALL

MODULE 18 AFQTP UNIT 1

SERVICE EQUIPMENT (18.1.2.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

SERVICE EQUIPMENT

Task Training Guide

STS Reference Number/Title:	18.1.2. - Distribution systems, 600 volts and less, install service equipment
Training References:	• CDC 3E051A, Vol. 4 • National Electrical Code Article 230
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool box
Learning Objective:	• Given equipment, install the service equipment
Samples of Behavior:	• Following approved method, install service equipment • Know safety requirements associated with installing service equipment
Notes:	
• Any safety violation will be an automatic failure.	

SERVICE EQUIPMENT

Background:
The service-entrance terminates in the service equipment and the distribution system begins in the service equipment. The service disconnect must be permanently marked to identify it as the service disconnecting means. The service equipment may be a separate switch, a panel board, or a combination. In addition to the switch or panel, the combination may include the wattmeter.
The service disconnects are required to have overcurrent protective devices to protect the conductors. These may be manually or power operated devices. However, it it is power operated, the disconnect must also be able to be manually operated. Several types of service disconnects are permitted. One of these is in the form of a **knife-blade switch** with one, two, or three blades, as needed, to open the ungrounded conductors. Another type of disconnect is installed as a **fuse block**. The fuse block contains a fuse for each ungrounded conductor. Removal of the fuse block has the same effect as opening a switch to interrupt current flow. A third method of providing for service disconnects and overcurrent protection is to use **circuit breakers**. These may be installed as a multi-pole assembly with a single switch handle. It is permissible to use up to six switches or circuit breakers as a disconnect. Single-pole switches or circuit breakers installed on a three-phase circuit should be equipped with handle ties or a master handle. The switch box is mounted on an inside wall directly behind the service entrance conduit. The conduit may be brought through the wall into the back of the switch box, as shown in Figure 1, or it may pass through the wall above the switch box and enter at the top.

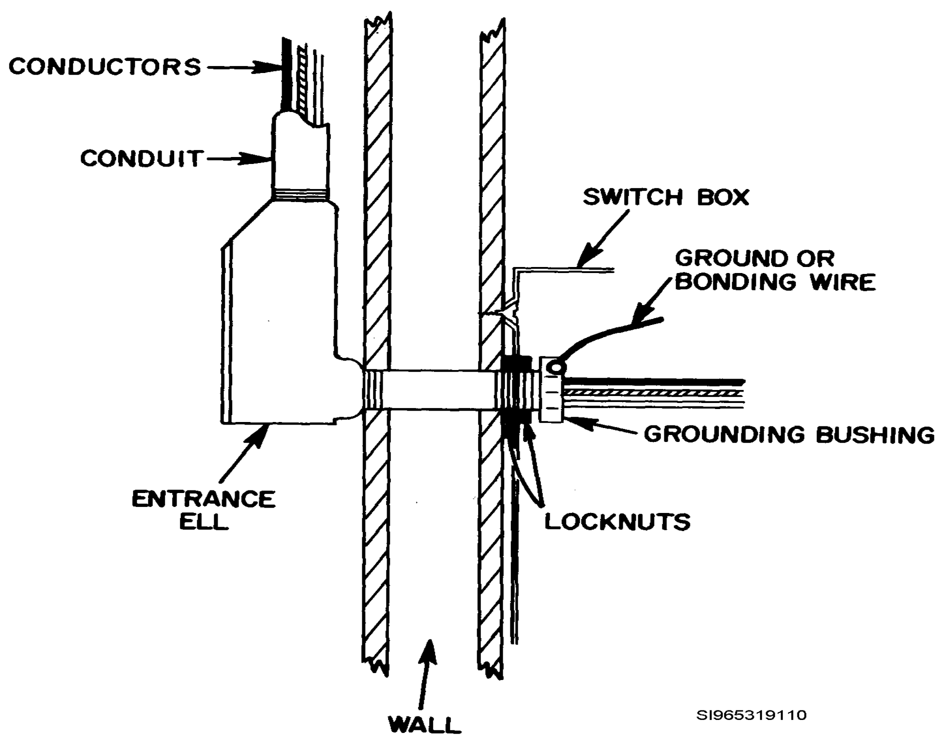

Figure 1, Switch Box Mount

The switch box has knockout plugs. The proper plug must be removed to provide an entry for the conduit. The switch box can be attached directly to the wall with screws if the wall has wood facing. Open studs may require that wood framing be built on which to mount the box. Masonry walls, such as concrete or brick, require the use of anchors for mounting purposes. Wooden plugs are banned for this purpose because they are likely to pull loose. After the conduit is attached to the box, grounding bushing similar to that shown in Figure 1 must be installed. The bushing may be grounded to the box or it may be connected to the neutral bus bar, depending on the specific installation.

NOTE:
All conduits must be bushed and grounded that enter or exit the box.

For most buildings there will be only one service drop; therefore, power must be distributed throughout the building using feeder circuits, panel boards, and branch circuits. Although the distribution system may start at the service disconnect, there can be several distribution panels throughout a facility. However, they should always be fed from one source. This main source is the only distribution panel where the grounding and grounded wire are bonded together. An example of one type of common set up would consist of power coming from the service drop, through the service-entrance to the service equipment. The service equipment would monitor power used in the wattmeter, control power and protect the conductors at the main disconnect (a fused safety switch), and supply power through the feeders to the distribution panel (a panel board). Although the panelboard may be used as the service disconnect, it is usually used as the primary power source for lighting and branch circuits.

Selection of a main disconnecting means.
- Consider the number of phases needed. If your disconnect is to be installed in a house, you will probably need a single-phase type. If you're in a commercial location, a three-phase disconnect will probably be needed.
- The location is an important factor also. If your disconnect is going to be outside it will need to be rain tight.
- Choose the type of service disconnect (switch type, panel with main, switch with meter, etc.).
- Determine whether you want a flush mount or surface mount panel.
- The most important consideration is selecting the right size. Your selection must consider the voltage and amperage needed for the facility.
- Once you have considered all these factors you will be ready to choose your disconnect.

Selection of wattmeter meter base.
- Consider the number of phases being used. Is it single or three phase?
- Consider the voltage and amperage being used.
- Determine the location. Is it internal or external?
- Determine what size and type of raceway or cable will be feeding into and out of it.
- Determine if it is a stand-alone meter with it's own base and enclosure, or if it shares it's enclosure with the main disconnect.

SAFETY: REMOVE ALL JEWELRY BEFORE BEGINNING ANY WORK. WHEN CONNECTING THE SERVICE ENTRANCE TO THE SERVICE DROP ENSURE THE LINES ARE DE-ENERGIZED.

Selection of distribution panel and cabinet.
- Consider the number of phases needed. If your panel is to be installed in a house, you will probably need a single-phase type. If you're in a commercial location, a three-phase panel will probably be needed.

- The location is an important factor also. If your panel is going to be outside you need a rain tight panel. If you have a switch outside, most times your panel will be indoors.
- Determine whether you want a flush mount or surface mount panel.
- The most important consideration is selecting the right size. Your selection must consider the voltage and amperage needed for the facility.
- Determine output capacity needed and how many separate circuits are to be fed. Make sure your panel will handle the circuit breakers required plus approximately 10% for expansion.
- Once you have considered all factors you will be ready to choose your panel and cabinet.

Mounting the meter base (for wattmeter).

- Mount the meter base to structure. Use the proper hardware for the type surface or medium. If it is concrete, then use concrete anchors and screws; if it is wood, then use wood screws; and if it is metal, use metal screws. Occasionally, walls have no support in the area you have to mount. In these instances, usually a brace is installed extending from secure areas and the meter base would then be mounted on the brace.
- Connect service mast to base (AFQTP 18.1.1).
- Connect raceway from base to panelboard cabinet.
- Connect service entrance conductors (Figure 2). Be careful as to the material that is used as conductors and the type of lugs on the base. If aluminum wires, you may need to change lugs or use a special compound to prevent corrosion.

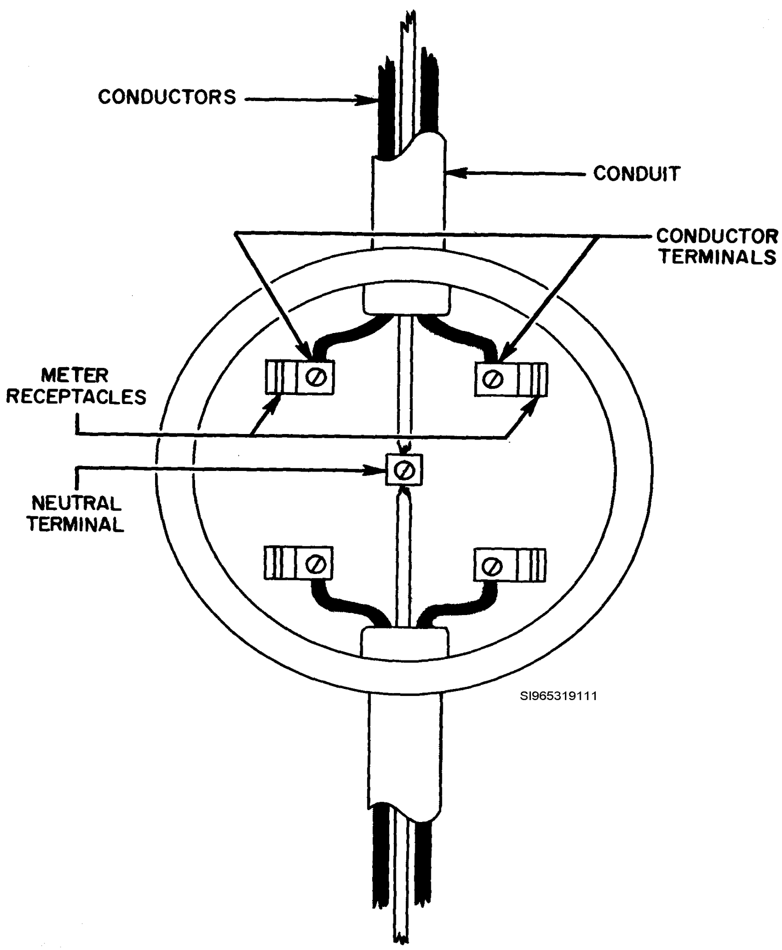

Figure 2, Wattmeter base

- If the service drop conductors are aluminum, special connectors are needed to prevent electrolytic corrosion from taking place between the aluminum and the copper service conductors.

> **NOTE:**
> Be sure to get the aluminum conductor in the proper space in these connectors.

Mounting the main disconnecting means.

- Mount the box.
- If the disconnect is to be flush mounted in the wall you can install screws through the side of the box and into the wall supports to hold the box in place.
- If the box is surface mounted, put the screws through the back of the box into the wall surface. Occasionally the surface will not adequately support the box, or the supports are too far apart. In this case, a brace is put across the wall between two supports and the disconnect is mounted to the brace.
- The type of fastener you use depends on the wall surface material.
- Bond the equipment ground bar and the neutral bar.

> Note:
> Metal raceways, meter sockets, safety switches, panelboard cabinets, and the grounding electrode conductor enclosure must be electrically bonded together to the grounding electrode conductor to be electrically continuous. This arrangement results in having all metal parts and enclosures in the service and the grounded conductor at the same potential electrically.

Mounting the Cabinet.

- Mount the box, which houses the panel.
- If the cabinet is to be flush mounted in the wall you can install screws through the side of the box and into the wall supports to hold the box in place.
- If the cabinet is surface mounted, put the screws through the back of the box into the wall surface. Occasionally the surface will not adequately support the box, or the supports are to far apart. In this case, a brace is put across the wall between two supports and the cabinet is mounted to the brace.
- The type of fastener you use depends on the wall surface material.

> **NOTE:**
> The grounding bus bar and neutral bus bar are only bonded at the service-entrance. They are not to be bonded anywhere else in the circuit.

Run Conduit or Cable.

- After the cabinet is mounted, the wiring for the circuits should be installed.
- Run circuit wiring in conduit or use nonmetallic cable.
- Remove the correct size knockout plug for the circuits you are installing. Remove only the knockout plugs that are needed for the circuits.

> **NOTE:**
> If a knockout is removed and the hole is not used, you must seal the hole with a plug or plate that affords protection equal to that afforded by the cabinet walls.

- Attach conduit directly to the cabinet with conduit fittings. You must bush the end of the conduit to provide a smooth, nonabrasive surface for the conductors. Insulated bushings are required for ungrounded No. 4 and larger conductors.
- Nonmetallic cable is brought into the cabinet through nonmetallic cable connectors attached to the cabinet.

NOTE:
Regardless of the wiring method, leave the ends of the conductors long enough to allow any conductor to be connected at any point within the cabinet.

Install Panel Board in Cabinet.
- After you bring all the circuits into the cabinet, mount the panel board in the cabinet.
- Also, attach the neutral bar and the equipment ground bar to the cabinet.
  Make sure to bond the ground bar to the cabinet by either a bonding jumper or the more common method of running a screw through the bar into the cabinet.

Connect Conductors.
- Often, pressure-type terminals are provided for larger conductors, neutral conductors, and equipment grounding conductors.
- Connect conductors in a neat and professional manner.
- All ground wires should be taken to the grounding bus bar.
- Neatly form all neutral conductors to run into the neutral bus bar.
- Connect phase conductors brought in through the sides of the cabinet directly to the overcurrent device.
- Those brought in from the top or bottom of the cabinet are neatly bent to a 90° angle opposite the fuse or circuit breaker to which they are to be attached and are cut just long enough to make a good connection.

NOTE:
Many experienced electricians feel that this system of connecting conductors is not necessarily the best, even though it presents the most uncluttered look and leaves more space around each conductor. These electricians usually try to leave an end on each conductor that is equal to the height plus the width of the cabinet. Run each conductor along the panel and loop back 180º before connecting it to its fuse or circuit breaker. Little added material is needed and the extra length on the conductor.

- The phase conductors in a fuse panel board are connected directly to terminals on the bus bars.
- The finished panel conductors should be neat and, if possible, the conductors should be tied and bundled together.

SAFETY:
USE PROPER TOOLS FOR THE JOB; AND USE THE TOOLS PROPERLY. BE ALERT AT ALL TIMES WHEN WORKING AROUND LIVE ELECTRICAL CIRCUITS OR PARTS.

Using most current NEC, determine type and size of service equipment required for overhead entrance using a meter base, external safety switch and interior panelboard.

Instructions: Although there are many variations and applications that are unique to the situation, listed below is one of the common types that is generally used. In all cases, the most current edition of the NEC should be used to ensure all code requirements and exceptions are met.

- Phasing and amperage requirements will be used to determine number of conductors as well as raceway, panel, wire and fuse sizing.

SAFETY NOTE: Always check and verify power is disconnected prior to working around service drop.

Step 1: Select equipment required

- meter base
- safety switch
- panelboard
- raceway

Step 2: Install meter base

- Correct size (phase, voltage and current)
- Correct type (weatherproof)
- Mounted correctly
- Bonded correctly

Step 3: Install Raceway

- Cut raceway to proper length, clean and thread
- Attach raceway between meter base and safety switch
- Secure raceway to structure
- Place grounding bushing on end of raceway except if a hub is used.
- Correct size
- Correct type
- Mounted correctly

Step 3: Install safety switch

- Correct size (phase, voltage and current)
- Correct type (weatherproof)
- Mounted correctly
- Bonded correctly

Step 4: Install Raceway

- Cut raceway to proper length, clean and thread
- Attach raceway between safety switch and cabinet for panelboard
- Secure raceway to structure
- Place grounding bushing on end of raceway except if a hub is used.
- Correct size
- Correct type
- Mounted correctly
- Bonded correctly
-

Step 5: Install cabinet for panelboard
- Correct size
- Correct type
- Mounted correctly
- Bonded correctly

Step 6: Install panelboard in cabinet
- Correct size
- Correct type
- Mounted correctly

Note:
Panelboard is usually left out of cabinet until after the wires have been pulled in place.

Review Questions
for
Service Equipment

Question	Answer
1. Power enters a building through the ______, which forms the main disconnecting means.	a. Service entrance b. Service equipment c. Service drop d. Service mast
2. A panel installed in a home will most commonly be what type of panel?	a. Single phase b. Double phase c. Three phase d. None of the above
3. What is the most important consideration when selecting a panel?	a. Location b. Number of phases c. Voltage and amperage d. Weather
4. Insulated bushings are required for ungrounded No. ___ and larger conductors.	a. 2 b. 4 c. 6 d. 8
5. Bond the grounding bus bar with the neutral bus bar in all distribution panels.	a. True b. False

SERVICE EQUIPMENT

Performance Checklist		
Step	**Yes**	**No**
1. Did the trainee select the proper panelboard and cabinet?		
2. Did the trainee select the proper safety switch?		
3. Did the trainee select the proper meter base?		
4. Did the trainee select the proper raceway?		
5. Did the trainee properly mount the meter base to the structure?		
6. Did the trainee properly mount the cabinet to the structure?		
7. Did the trainee properly connect the entire conduit or cable?		
8. Did the trainee install the panel board in the cabinet?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

INSTALL

MODULE 18 AFQTP UNIT 1

SYSTEM AND EQUIPMENT GROUNDS (18.1.3.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

SYSTEM AND EQUIPMENT GROUNDS

Task Training Guide

STS Reference Number/Title:	18.1.3. - Distribution systems, 600 volts and less, install system and equipment grounds
Training References:	• CDC 3E051 A Vol. 3 • National Electric Code
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• Ground rod driver • Wire • Connectors • Adjustable Wrenches
Learning Objective:	• Given equipment, install system grounds • Given equipment, install equipment grounds
Samples of Behavior:	• Follow the required steps to install system grounds • Follow the required steps to install equipment grounds • Know safety requirements associated with installing system grounds • Know safety requirements associated with installing equipment grounds
Notes:	
• Make sure the power is de-energized before disconnecting any existing building grounds.	

SYSTEM AND EQUIPMENT GROUNDS

Background: The grounding electrode is the point of the wiring system where the ground potential is established. The grounding electrode can take many forms ranging from a manmade metal rod to the building structure. When establishing a grounding electrode system, it is a good idea to use as many of these electrodes as possible to get the maximum ground potential possible.

The grounding system consists of the circuits in an electrical installation that connects all metal parts of the installation together. Grounding conductors are green, green with a yellow stripe, or bare, meaning no insulation at all. The grounding system provides an alternate path for current and provides protection from shock.

Grounding systems provide an alternate path of low resistance back to the source (main disconnect). Grounding conductors are connected to the metal parts of equipment and under normal conditions carry no current. During those times when a fault current such as a short circuit to the metal parts of the equipment occurs, the grounding conductor provides a path to carry that current back to the main disconnect with a very low resistance. The low resistance return allows the current in the circuit to go extremely high. The high current is essential in order for the circuit breaker to open. The higher the current, the quicker the breaker will open.

The grounding system also provides protection from shock. If the metal parts of a piece of equipment were not grounded, then any fault current would wait in the metal for a path to ground to flow through. You may unknowingly provide that path through your body just by touching the surface of the equipment. By providing a path in the form of a grounding circuit, the fault current will flow through it and trip the circuit breaker, opening the circuit and through this action prevent electrical shock hazard. The following systems and equipment must be grounded:

- Service raceways and enclosures for service conductors and equipment shall be grounded.
- All metal enclosures shall be grounded.
- Equipment fastened in place or fixed equipment (permanent wiring) that has exposed non current-carrying metal parts likely to become energized shall be grounded.

Normally, a pipe in the water system is used as one of the grounding electrodes. If for some reason the water system can't be used, the metal structure of the building may serve the purpose or metal rods may be driven into and buried in the ground as a grounding electrode. Once a suitable grounding electrode is identified, attach the grounded or neutral conductor. The grounding-electrode conductor is installed as a continuous conductor from the neutral bus bar to the grounding electrode. Small grounding conductors are enclosed in a protective metal covering that should be electrically continuous from the panelboard cabinet to the grounding electrode.

Equipment grounding conductor connections shall be made at the service equipment in the following manner:

- For a grounded system: (with a neutral conductor) bonding the equipment-grounding conductor to the grounded service conductor and the grounding electrode conductor shall make the connection.

- For an ungrounded system: (no neutral conductor) bonding the equipment-grounding conductor to the grounding electrode conductor shall make the connection.

Determine What Type of Grounding Electrode is Available. Do you have:

- A ground ring at least 20 feet long made of at least #2 AWG copper encircling the building at a depth of at least 2 feet.
- The metal frame of a building.
- An electrode encased by at least two inches of concrete located within and near the bottom of a concrete foundation or footing that is in direct contact with the earth.
- Metal underground water pipe in direct contact with the earth (uncoated) for 10 feet or more.
- 5/8” x 8’ copper clad rod.
- ¾” X 8’ galvanized pipe.

Installation of a Grounding Conductor.

- Connect conductor to ground electrode with a suitable connector, exothermic weld, listed pressure connectors, or listed clamps.
- Connect grounding conductor to lug in the panel using a suitable connector.
- Bond the grounding conductor and the grounded (neutral) conductor on the line side of the service entrance disconnect.(see Note 2 below)
- Bond all grounding electrodes available (water pipes, metal structures, rebar in conduit, and ground rings to the system ground.

NOTE 1:
If water pipe is the only available ground electrode, a ground rod must supplement it.

NOTE 2:
The reason the grounded circuit conductor is not bonded to the neutral anywhere besides the line side of the service entrance disconnect is to provide a safer system. Should the grounded service conductor become disconnected at any point on the line side of the ground, the equipment grounding conductor and all metal parts connected to it will carry the neutral current. This could cause arcing in concealed spaces and

Installing A Ground Rod.

- Drive the ground rod to or slightly below grade level when no protective covering is to be installed.
- If rod cannot be driven vertically because of soil conditions, it must be driven at an angle not to exceed 45 degrees, or it may be buried lengthwise a minimum of 2 1/2 feet below grade. See Figure 1.

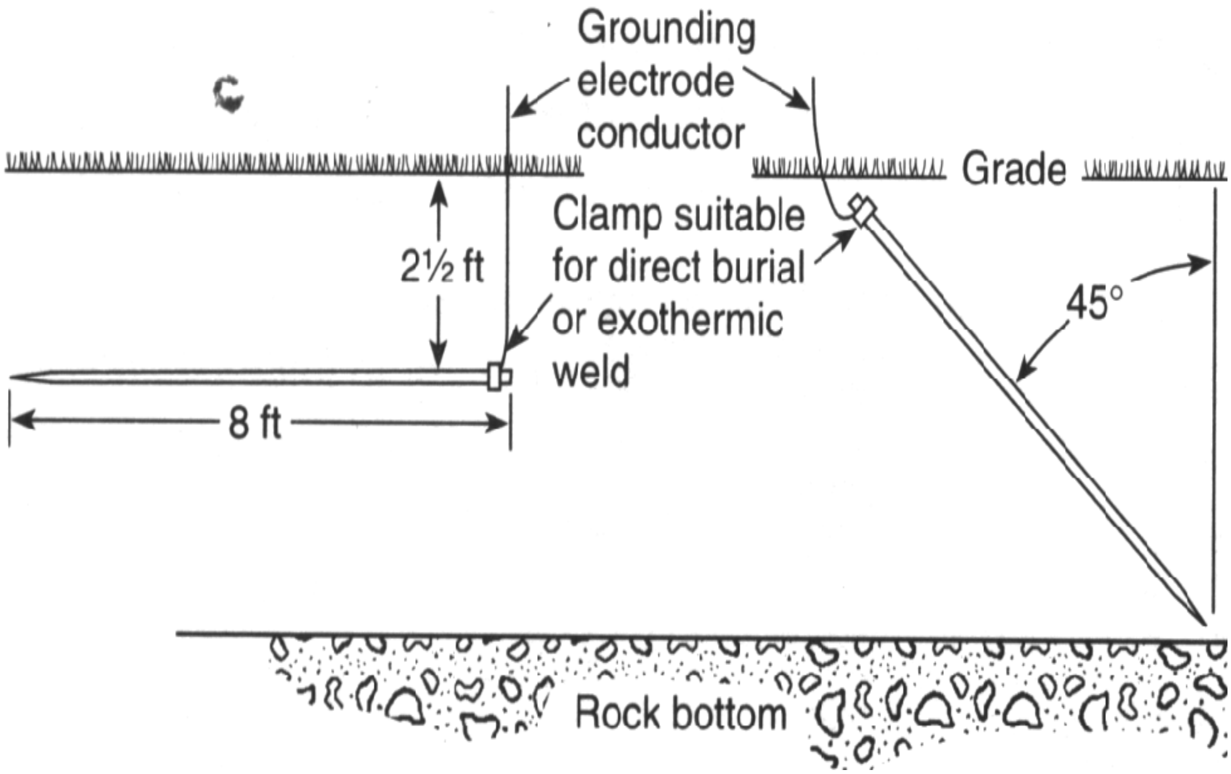

Figure 1, Ground Rod Installation

Review Questions
for
System and Equipment Grounds

Question	Answer
1. Where can the grounded (neutral) and the grounding conductor be bonded together?	a. On the service drop. b. On the load side of the service entrance disconnect. c. On the line side of the service entrance disconnect d. Where the service drop enters the mast.
2. What is the minimum size of the ground rod electrode?	a. 5/8 diameter by 8 ft long b. ¾ diameter by 10 ft long c. 5/8 diameter by 10 ft long d. ¾ diameter by 8 ft long
3. Water pipe (uncoated) and direct buried in earth for a minimum of 10 feet can be used as a stand alone ground electrode.	a. True b. False
4. How deep must a ground rod for facility system ground be driven when no protective covering is provided?	a. 6 inches below grade b. level to grade c. 6 inches above grade d. level to or slightly below grade
5. If a ground rod cannot be driven vertically because of soil conditions it may be driven at a ___-degree angle from the vertical.	a. 25 b. 50 c. 75 d. None of the above
6. ½" Galvanized iron pipe cannot be used for a grounding electrode.	a. True b. False
7. What is the minimum size copper conductor and burial depth for a ground ring?	a. # 6 AWG 18 inches b. # 4 AWG 24 inches c. # 2 AWG 30 inches d. # 1/0 AWG 36 inches

SYSTEM AND EQUIPMENT GROUNDS

Performance Checklist		
Step	**Yes**	**No**
1. Did trainee determine the type of ground required?		
2. Did trainee install ground conductor with the proper connector?		
3. Did trainee install ground electrode to or below grade level?		
4. Did trainee bond ground conductor and neutral conductor on the line side of the service entrance disconnect?		
5. Did trainee bond all grounding systems together?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

INSTALL

MODULE 18 **AFQTP UNIT 1**

FEEDERS (18.1.4.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

FEEDERS

Task Training Guide

STS Reference Number/Title:	18.1.4. - Distribution systems, 600 volts and less, install feeders
Training References:	• CDC 3E051A, Vol. 4 • National Electrical Code, Article 215, Feeders
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• Fish tape • Electrical tape • General tool kit • Approved lubricant
Learning Objective:	• Install feeder circuits
Samples of Behavior:	• Follow required steps to install feeder circuits • Know safety requirements associated with installing feeder circuits
Notes:	
• Any safety violation is an automatic failure.	

FEEDERS

Background: Electrical circuits installed in a building are either branch circuits or feeder circuits. Feeder circuits might be described as those that deliver power to the final overcurrent devices.

Small buildings usually have one main distribution panel board to which the branch circuits are connected. When the distribution panel is combined with the service equipment, there is no need for a feeder circuit. However, when the distribution panel is separate, a feeder circuit is needed to get power from the service equipment to the distribution panel. Feeder circuits may be installed by any method approved by the NEC for the installation of electrical circuits.

Larger buildings require more than one panel board to meet their power needs. Feeder circuits are installed to supply power from the main panel board to panel boards installed elsewhere in the building. Although the main panel board may be used for both branch circuits and feeder circuits, it is usually limited to feeder circuits on a separate panel board.

Other panel boards, which are supplied by feeder circuits from the main panel board are used for branch circuits. In some cases, a panel board at the end of a feeder circuit becomes a junction point to which sub-feeders are attached. These sub-feeders, in turn, supply branch circuit panel boards. Consequently, through the installation of feeder circuits, it is possible to use a single set of large conductors to replace several long small conductors that are required when all branch circuits connect to the main entrance panel board. Feeder circuits allow panel boards to be located so that the wiring needed for branch circuits is greatly reduced. Generally, such circuit arrangements reduce voltage loss in the conductors and save material and labor.

The main objective is to install circuits so troubles and hazards are kept at a minimum consistent with existing conditions. Usually, you use nonmetallic cable for circuits that are not subject to damage or excessive dampness. Also, circuits may be installed in metal raceways, rigid nonmetallic raceways, and cable trays. Feeder circuits can be installed with a common neutral to serve two or three sets of three-wire feeders, or two sets of four- or five-wire feeders. Feeders installed in a metal raceway and that use a common neutral must have all the conductors involved enclosed in the same raceway. A feeder that supplies branch circuits having grounded conductors must provide a grounding means to which the branch circuits grounding conductors are connected.

SAFETY:
WHEN PERFORMING ANY ELECTRICAL WORK ALWAYS WEAR EYE PROTECTION WHEN NECESSARY. WHEN USING STEPLADDERS, DON'T STAND ON THE TOP STEP OF THE LADDER. DON'T USE THE LADDERS AS A WORKBENCH. ALWAYS BE ALERT AT ALL TIMES WHEN WORKING AROUND LIVE ELECTRICAL CIRCUITS OR PARTS.

NOTE:
While nearly all types of wire may be used in conduit installations, the most common types used are those made with thermoplastic insulation. No matter what type of wire is installed always be sure to pull in enough for the job. Be sure to leave plenty in the panel for connections.

To perform the tasks, follow these steps:

Step 1: Pulling Conductors.

- For short conduit runs with few wires, the conductors can be pushed through the conduit from one box to the next.
- When the conduit has several bends it may be necessary to use a fish tape to pull the wires through the conduit.
- The fish tape normally has a hook on one end, which is pushed through the conduit.
- The hook makes it easier to push the tape through and provides a method of attaching the conductors for pulling.
- Once you have the fish tape in the conduit, attach the hook to the wires to be pulled, as shown in Figure 1.

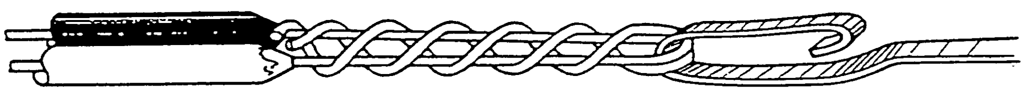

Figure 1, Wires Attached to Fish Tape

- Remove 4 to 6 inches of the insulation from the ends of the wires.
- Thread them through the hook in opposite directions; bend them back and twist them around each other.
- Then tape the hook and bare conductors to strengthen the attachment and make pulling easier.
- Use just enough tape to cover the hook and wires.

NOTE:
Wire pulling usually takes two people. One to pull the fish tape, the other to feed the conductors into the conduit. The fish tape should be fed into the conduit end from which it is easiest to pull.

SAFETY:
WHENEVER CONDUCTORS ARE BEING PULLED INTO A ENERGIZED PANEL, BE CAREFUL TO KEEP CLEAR OF THE BUSBARS, AND PULL CONDUCTORS FROM THE PANEL TO THE FIRST JUNCTION BOX. ALL ENERGIZED PARTS SHOULD BE COVERED WITH A RUBBER BLANKET.

- When several conductors must be fed into a conduit, you should keep them parallel and straight and free from kinks and bends.
- Wires that are allowed to cross each other form a bulge and are hard to pull around bends.
- Whenever possible, feed conductors downward; (e.g., from the second floor to the first), so the weight of the wires will help in the pulling process.
- Another way to ease the pulling of conductors is to rub an approved lubricant, such as soap, talc, soapstone, or other non corrosive substance, onto the insulation or blow it into the conduit.

- You may find that it is hard to keep the fish tape from slipping in your hands when pulling long runs with several bends.
- When this is a problem, the back side (insulation crushing point) of a pair of lineman's pliers may be used to grip the tape to give you a good pulling handle.

Step 2: Connecting Feeders.

- Ohm the cable to ensure no open, shorts or ground was incurred in the pulling process.
- After the cable has been tested, connect the your cable to the panel board you are feeding.

NOTE:
As good practice always begin your connections at the equipment you are feeding and work back towards your source.

- Start the connecting with the ground conductor, then the neutral, and finally the phase connections.
- Now repeat the same operation at the source panel.

SAFETY:
ALL ENERGIZED PARTS SHOULD BE COVERED WITH A RUBBER BLANKET. ENSURE THAT ALL STINGER LEGS ON THREE-PHASE FEEDERS ARE CONNECTED TO THE B-PHASE IN ALL PANEL BOARDS AND PROPERLY

NOTE:
Some connections may vary depending on the service being provided. Some examples of different services are shown in Figure 2.

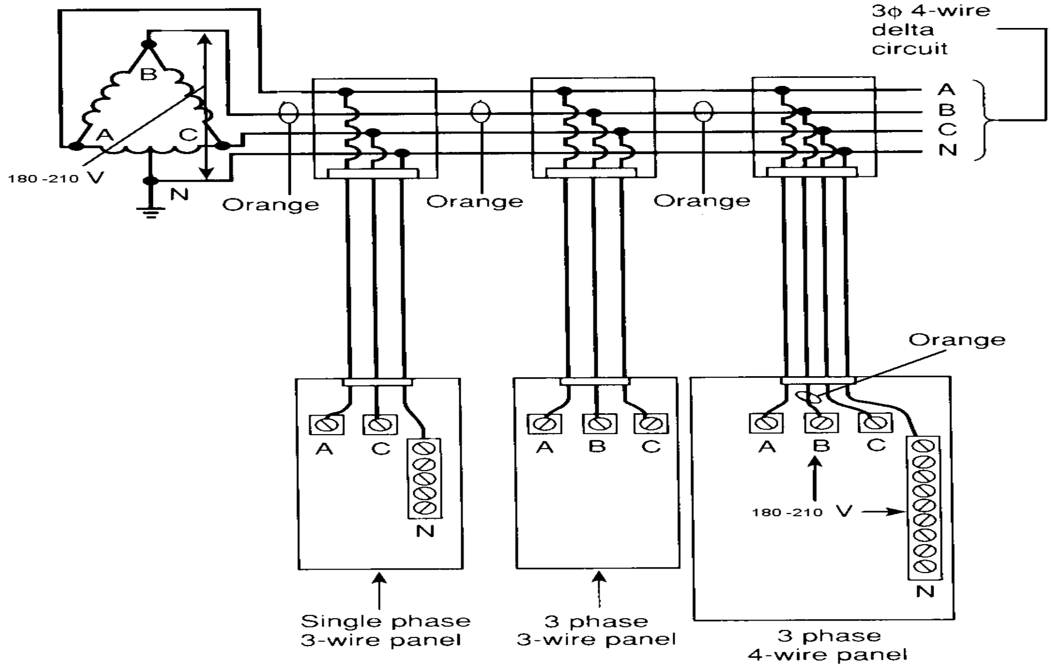

Figure 2, Various Feeder Connections

Review Questions
for
Feeders

Question	Answer
1. Electrical circuits installed in buildings are ______.	a. Branch. b. Equipment. c. Feeder. d. A & C.
2. The Main objective is that circuits installed keep troubles and hazards to a minimum.	a. True b. False
3. Remove ___ to ___ inches of insulation from wires for connection to the fish tape.	a. 1- 2 b. 2 – 4 c. 4 – 6 d. 6 –8
4. Which of the following is an approved lubricant used for pulling of cables?	a. Motor oil b. Talc c. Vegetable oil d. Anti-cease grease
5. Before connecting panel boards, test for ____.	a. Opens. b. Shorts. c. Grounds. d. All of the above.
6. The first conductor connected is the ___.	a. Neutral. b. Ground. c. A phase. d. Control Cable.
7. What conductor must be labeled and identified with orange tape in a Delta system?	a. Ground b. B phase c. Stringer leg d. None of the above

FEEDERS

Performance Checklist		
Step	**Yes**	**No**
1. Did trainee remove 4 – 6 inches of insulation from wire ends before attaching to fish tape?		
2. Did trainee keep wires free from kinks and bends?		
3. Did trainee test the cable for opens, shorts, and grounds before starting connections?		
4. Did trainee start connections in the panel board that they are feeding?		
5. Did trainee connect all stinger legs to the B phase in all panels and mark with orange tape in a Delta system?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

INSTALL

MODULE 18 **AFQTP UNIT 1**

DISTRIBUTION PANELS AND PROTECTIVE DEVICES (18.1.5.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

DISTRIBUTION PANELS AND PROTECTIVE DEVICES

Task Training Guide

STS Reference Number/Title:	18.1.5. - Distribution systems, 600 volts and less, install distribution panels and protective devices
Training References:	• CDC 3E051A Vol. 4 • National Electrical Code, Article 384
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool box
Learning Objective:	• Given equipment, install distribution panels • Given equipment, install protective devices
Samples of Behavior:	• Follow the appropriate steps to install a distribution panel • Follow the appropriate steps to install protective devices • Know safety requirements associated with installing distribution panels • Know safety requirements associated with installing protective devices
Notes:	
• Any safety violation will be an automatic failure.	

DISTRIBUTION PANELS AND PROTECTIVE DEVICES

Background: Once power is brought into a building it needs to be divided and sent out to the points where it is going to be used. A distribution panel/panel board, as its name implies, serves as a center or point in the electrical system where the power is fed to the branch circuits. There is only one distribution panel in a building when the requirement is for lighting and power is not too large. On the other hand, several panels may be required in a large building, or one in which quite a lot of electrically powered equipment is to be operated. A distribution panel consists mainly of a metal cabinet that houses bus bars and individual circuit protective devices. The protective devices (fuses and circuit breakers) protect the circuits against excessive current flow. Distribution panels are divided into categories according to the purpose for which the circuits are to be used. They may also be classed according to the type of protective devices used with the panel.

Distribution panels are classed generally as lighting and appliance panels, power panels, or feeder panels. Any panel that has *more than* 10 percent of its overcurrent devices rated at 30 amperes or less and has provisions for neutral connections is classified as a lighting and appliance panel. These panels provide connections for branch circuits that are used for both lighting and power purposes. Power panel boards are used mainly to provide power for the operation of electrical equipment. Most of the branch circuits from a power panel are 240 or 480 volts. However, some lighting circuits may be provided. Feeder panel boards distribute power to other panel boards located at various points in a building. These other panelboards can be either power panels or lighting and appliance panels. These added panel boards allow branch circuits to be installed where they are the most useful, with an overall savings in material. Panel boards must be rated at least as high as the feeder capacity required for the load. The manufacturer marks the panel boards with the voltage, current rating, and number of phases for which they are designed. Interior parts must not obstruct this information, plus the manufacturer's name or trademark, or wiring after the panel board is installed. According to the *NEC®*, (art. 384–15) lighting and appliance panel boards can't have more than 42 overcurrent devices besides the mains. Two-pole and three-pole circuit breakers are counted as two and three overcurrent devices respectively. According to the *NEC®* (art. 384–16), each lighting and appliance panel board must be protected from current flow on the supply side by not more than two main circuit breakers or two sets of main fuses having a combined rating no greater than the panel board. This protects not only the feeders, but also the panel board bus bars. Individual protection is not needed if the panel board feeder has overcurrent protection no higher than the panel board rating. The total load on any single overcurrent device in a panel board must not exceed 80 percent of its capacity where, in normal use, the load continues for 3 hours or longer to prevent overheating of the conductor.

Panel board cabinets must be grounded. A terminal bar must be provided for attachment of feeder and branch-circuit equipment-grounding conductors where nonmetallic raceway or cable is used. This terminal bar must be bonded to the cabinet, but not to the neutral bar except in service equipment. Three-phase panel boards supplied by a four-wire, delta-connected system that has the midpoint of 1-phase grounded, must have the higher voltage phase-to-ground conductor or bus bar marked. This high-voltage conductor should have an orange outer finish or be tagged clearly. The identification is required at any point where a connection can be made and the neutral conductor is also present. The phase arrangement on a three-phase panel board is A, B, C, from left to right or top to bottom when viewed from the front. The B phase is the phase that has the higher phase-to-ground voltage.

Fuse panels, as the name implies, contain fuses for protection of each circuit. You find there are many designs of fuse panels. These designs vary in size, capacity (amperage and voltage), and type of installed fuses. The capacity of the panel is based on the amperage rating of the panel's bus bars. This type of panel may be either surface or flush mounted. The cabinet or case has knockouts so that conduit or cable connectors can be attached directly to it. When supplying power to general branch circuits, you must use dead front designed panels. This means that when the door on the panel is open, no live parts are exposed. You must remove the cover from the panel to gain access to the interior parts.

Fuse panels are designed for plug fuses, cartridge fuses, knife-blade fuses, or a combination of these. Fuse panels that use an Edison-base fuse are called a plug fuse panel. Don't install these fuse panels for new work or as a replacement panel unless they have been modified to accept type S fuses. (Adapters that will accept only type S fuses are installed in the fuse holders.) Type S plug fuse panels that don't need adapters are available also. Cartridge fuse panels use either the ferrule or knife-blade type fuses, depending on the capacity of the panel. All the fuses listed here will be covered in the section on protective devices.

Type S plug fuses and the Edison-base-type screw into sockets similar to an ordinary light socket. Plug fuses are used from 0 to 30 amperes at a maximum of 125 volts. Plug fuses have a clear glass or mica window directly over the fuse element. This window provides a means for determining visually whether the fuse is good or blown. Fuses rated from 0 through 15 amperes have a hexagonal window, while those rated from 16 through 30 amperes have a round window. Plug fuses must be screwed in firmly for good contact, but not tight enough to make them difficult to remove. Edison-base fuses may be used only for replacements in existing installations. Plug fuse panels used in new work must be modified so that the type S fuse must be used. Type S plug fuses require an adapter. The adapter is designed so that once it is screwed into place, it cannot be removed. Type S fuses and adapters come in three capacity ranges: 0 through 15 amperes, 16 through 20 amperes, and 21 through 30 amperes. The advantage to this system is that fuses of a larger ampere rating will not fit into an adapter of a lower ampere capacity range. In addition, this prevents objects such as pennies and wire, from being inserted into the socket to override the protection.

Cartridge fuses are of two types: the ferrule and the knife-blade type . Both types are available with replacement or non-replaceable fuse links. Ferrule-type fuses are available in ampere ratings from 0 through 60. Fuse panels that use ferrule-type fuses have specially designed fuse clips in which only ferrule types will fit. A 60-ampere, ferrule type can't be used in place of a 20-ampere because fuse diameter and length increase as amperage and voltage increase. Ferrule-type fuses are used in circuits up to 600 volts. Fuse panels that provide distribution for high-capacity circuits use knife-blade fuses for protection. The fuse clips are designed especially to receive knife-blade fuses only. Knife-blade fuses are available in ampere ratings of 61 through 6,000. The maximum voltage rating for knife-blade fuses is 600 volts. When selecting fuses for circuit protection, consider two factors:

- The total current flow.
- The voltage of the circuit in which the fuse is to be installed.

Since the purpose of the fuse is to protect the circuit, it must be the weakest point in the circuit. Thus, the fuse used should be rated no higher than the lowest-rated component to be protected. Before installing a fuse in a panel, check the condition of the fuse holder or clips. These must be clean and hold the fuse firmly.

Circuit breaker panels serve the same purpose as fuse panels. Generally, they resemble fuse panels except for the protective devices used in the circuits. Circuit-breaker panels are preferred to fuse panels because a circuit breaker needs only to be reset after it is tripped by an overload condition. Fuses, on the other hand, must be replaced after they are blown. An added convenience of the circuit breaker is that it can be a switch to manually disconnect a circuit from its power sources. Circuit breaker panels must have the dead front design the same as fuse panels. Replacement of individual circuit breakers requires that the front cover be removed. One of the newer types of protective devices, used more often than fuses because of the way it reacts to an overload, is the circuit breaker. A circuit breaker trips on an overload but can be reset to complete the circuit again without removal or replacement. Circuit breakers are classed according to their operating principles: thermal, magnetic, or a combination thermal-magnetic. Circuit breakers may be ordered with one, two, or three poles. Multi-pole breakers open all ungrounded conductors in a circuit at the same time.

A thermal-type circuit breaker has a bimetallic element within the breaker that responds to temperature change. Fusing together two strips of dissimilar metal makes the bimetallic element. Each strip has a different expansion rate when heated. Current flowing through the breaker generates heat that increases as the flow increases causing the bimetallic element to bend and act against a latch. The breaker mechanism is adjusted so that when the current flow reaches a set level, the element bends enough to trip the latch. This action opens a set of contacts to break the circuit. Usually, you refer to the thermal-type circuit breaker as a time lag breaker because the breaker does not open immediately when an overload occurs. The bimetallic element requires a short time (length depends on the size of the overload) to respond to the heat generated by the overload current.

A magnetic-type circuit breaker responds instantaneously when an excess of current flows through the breaker. A small electromagnet actuates the breaker mechanism. Whenever a predetermined amount of current flows through the electromagnet, enough magnetic flux is created to attract a small armature. As the armature moves, the breaker mechanism trips and opens the circuit.

The thermal-magnetic circuit breaker, as the name implies, combines the features of both the thermal and the magnetic types. Of the three, the thermal-magnetic circuit breaker is preferred for general use. A small overload actuates the bimetallic strip to open the circuit on a time delay, while a large overload or short circuit actuates the magnetic trip to open the circuit instantly. Circuit breakers are rated in amperes and volts the same as fuses, and you select them on the same basis. Circuit breakers are sealed units and no attempt should be made to adjust the ampere capacity or to repair it. A defective breaker must be removed and replaced. Circuit breakers that are to be used in circuits that may pose an added hazard to the user are made with an extra safety feature. This breaker is called a ground fault circuit interrupter (GFCI). It is a thermal-magnetic breaker with an additional internal circuit that detects a current leak from the hot wire to ground and opens the breaker if that current reaches a set amount. This leakage cannot be more than 5 (+1) milliamperes (thousandths of an ampere) to ground.

Most of these breakers have a test button that can check the GFCI to see whether it will trip when there is a fault. In Figure 1, you see a GFCI installed. You connect the circuit hot wire to the breaker the same as you do on a standard breaker.

The circuit neutral is connected to another terminal on the GFCI instead of to the neutral bar in the panel. The GFCI comes with an attached white neutral wire, which you then connect to the neutral bar. The *NEC®* (art. 210–8) requires that GFCIs be installed for several circuits used in the home. These circuits include ALL 125-volt, single-phase, 15- and 20-ampere receptacles in bathrooms, garages, and outdoors. GFCIs may be used elsewhere when there is a need for the added protection.

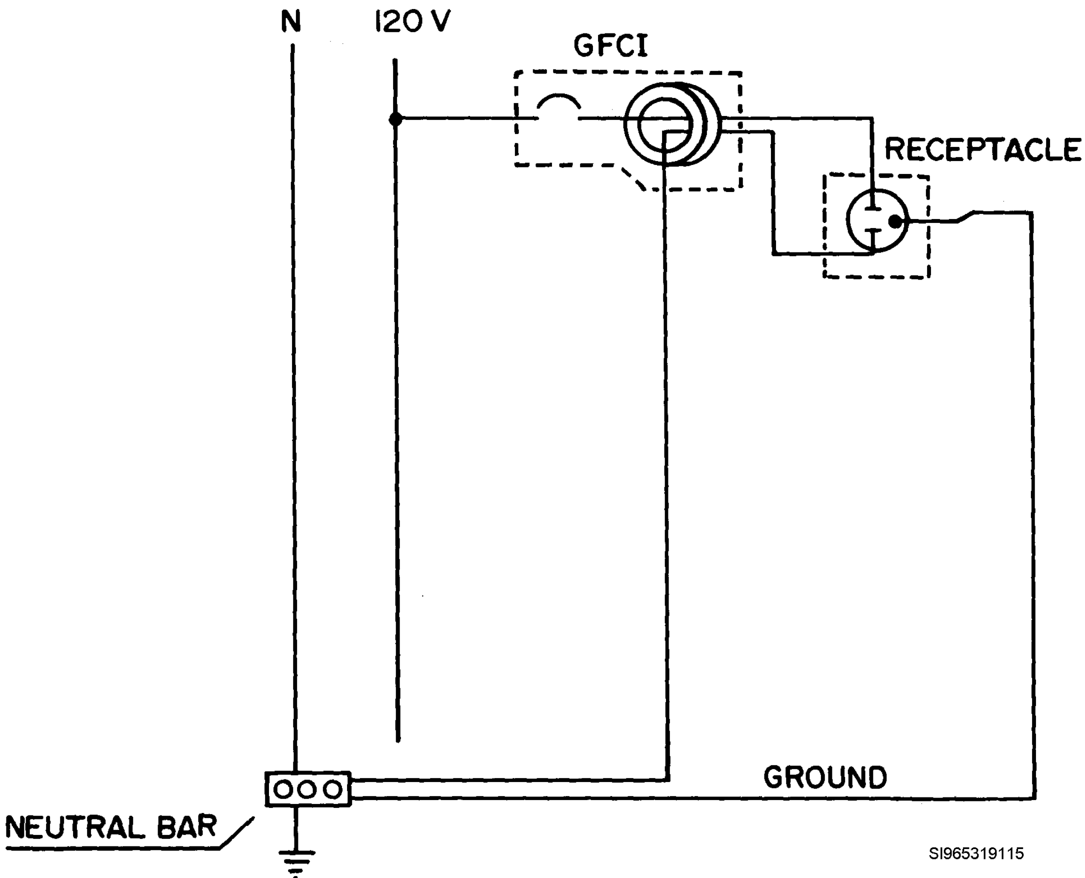

Figure 1, GFCI Installations

To perform the tasks, follow these steps:

Step 1: Select a Panel Board.

- There are several items to consider when selecting a distribution panel. Electrical equipment is very expensive and you should carefully consider all options that are available with any installation. Normally these will be designed by the electrical engineer responsible for the building design. Ensure the panel selected meets all design and specification requirements.
- Select one that provides an adequate number of spaces for the circuits to be installed. The number of required circuits is determined by the size of the building and the equipment to be used in it.

> **NOTE:**
> You usually select a panel board that provides at least one unused overcurrent protective device when only a few circuits are installed. When many circuits are installed, it is common practice to leave two or more unused spaces for future expansion.

- Consider the number of phases needed.

> **NOTE:**
> If your panel is to be installed in a house, you will probably need a single-phase type. If you're in a commercial location, a three-phase panel will probably be needed.

- Choose the type of service disconnect (e.g. switch type, panel with main, etc.).
- The location is an important factor also. If your panel is going to be outside you need a rain tight panel.
- Determine whether you want a flush mount or surface mount panel
- The most important consideration is selecting the right size. Your selection must consider the voltage and amperage needed for the facility.
- Once you have considered all these factors you will be ready to choose your panel and cabinet.
- Again, you should ensure the panel selected meets all design and specification requirements as stated by the electrical engineer of record. The engineer is the responsible person for making sure the panel meets all code conditions.

Step 2: Install Cabinet.

- Remove interior parts of panel before mounting cabinet.
- Mount the box, which houses the panel.
- If the structure has wooden studs in the walls, you can install screws through the side of the box into the wood to hold the box in place.
- If the box is surface mounted, put the screws through the back of the box into the wall surface.
- The type of fastener you use depends on the wall surface material.

> **NOTE:**
> Cabinets installed in damp locations must have at least ¼ -inch airspace behind the cabinet to allow for air circulation.

- Attach a surface-mounted cabinet to the wall with screws, hollow wall fasteners, or masonry anchors. Spacers are placed behind the cabinet, if needed.
- A cabinet that is to be flush-mounted on a frame wall may need to have framing added.

> **NOTE:**
> In walls built of concrete, tile, or other noncombustible material, cabinets are recessed with the front edge up to 1/4 inch from the finished surface. Cabinets in wood or other combustible walls must either be flush or project from the surface.

Step 3: Run Conduit or Cable.

- After the cabinet is mounted, the wiring for the circuits should be installed.
- Run circuit wiring in conduit or use nonmetallic cable.
- Remove the correct size knockout plug for the circuits you are installing. Remove only the knockout plugs that are needed for the circuits.

> **NOTE:**
> If a knockout is removed and the hole is not used, you must seal the hole with a plug or plate that affords protection equal to that afforded by the cabinet walls.

- Attach conduit directly to the cabinet with conduit fittings.
- You must brush the end of the conduit to provide a smooth, nonabrasive surface for the conductors.
- Insulated bushings are required for ungrounded No. 4 and larger conductors.
- Nonmetallic cable is brought into the cabinet through nonmetallic cable connectors attached to the cabinet.

> **NOTE:**
> Regardless of the wiring method, leave the ends of the conductors long enough to allow any conductor to be connected at any point within the cabinet.

Step 4: Install Panel Board in Cabinet.

- After you bring all the circuits into the cabinet, mount the panel board in the cabinet.
- Also, attach the neutral bar and the equipment ground bar to the cabinet.
- Bond the ground bar to the cabinet by either a bonding jumper or the more common method of running a screw through the bar into the cabinet.
- Do not bond the equipment ground bus bar and the neutral bus unless the panel is being used as the service entrance to the building.
- Place circuit breakers in panel. Most panels have snap-in breakers; however, some may bolt on directly to the bus bar.

Step 5: Connect Conductors.

- Connect conductors in a neat and professional manner.
- All ground wires should be taken to the grounding bus bar.
- Neatly form all neutral conductors to run into the neutral bus bar.
- Connect the phase conductors evenly between the phases to keep the loads balanced.
- Connect phase conductors brought in through the sides of the cabinet directly to the overcurrent device.
- Those brought in from the top or bottom of the cabinet are neatly bent to a 90° angle opposite the fuse or circuit breaker to which they are to be attached and are cut just long enough to make a good connection.

> **NOTE:**
> Many experienced electricians feel that this system of connecting conductors is not necessarily the best, even though it presents the most uncluttered look and leaves more space around each conductor. These electricians usually try to leave an end on each conductor that is equal to the height plus the width of the cabinet. Run each conductor along the panel and loop back 180º before connecting it to its fuse or circuit breaker. Little added material is needed and the extra length on the conductor permits it to be switched to another terminal on the panel. Also, in case of conductor breakage near the terminal, the conductor is reconnected easily.

- Connect the phase conductors in a fuse panel board directly to terminals on the bus bars.
- The finished panel conductors should be neat and, if possible, the conductors should be tied and bundled together.

SAFETY:
IF THE PANEL YOU ARE INSTALLING IS BEING FED FROM ANOTHER DISTRIBUTION PANEL; BE SURE THE LINES ARE DE-ENERGIZED, BLOCKED, AND TAGGED BEFORE CONNECTIONS ARE MADE.

Review Questions
for
Distribution Panels and Protective Devices

Question	Answer
1. A ________ serves as a center or point in the electrical system where the power is fed to the branch circuits.	a. Cabinet b. Distribution panel c. Fuse d. Circuit breaker
2. What is the purpose of the protective devices in a panel board?	a. Protect the circuit against excessive current flow. b. Prevent water from entering the panel c. Protect circuit from high voltage. d. Both a and c
3. Any panel that has *more than* 20 percent of its overcurrent devices rated at 30 amperes or less and has provisions for neutral connections is classified as a lighting and appliance panel.	a. True b. False
4. _____ panel boards distribute power to other panel boards located at various points in a building.	a. Distribution b. Fuse c. Feeder d. Power
5. Edison-base fuses may be used in new installations.	a. True b. False
6. What are the two types of cartridge fuses?	a. Edison base and Type S b. Edison base and switchblade c. Switchblade and ferrule d. Knifeblade and ferrule
7. A thermal-type circuit breaker has a bimetallic element within the breaker that responds to ___________ change.	a. Voltage b. Load balance c. Temperature d. Frequency
8. Cabinets installed in damp locations must have at least __ inch airspace behind the cabinet to allow for air circulation.	a. ¼ b. ½ c. ¾ d. none of the above
9. Always bond the equipment ground bus bar and the neutral bus in the panel.	a. True b. False

DISTRIBUTION PANELS AND PROTECTIVE DEVICES

Performance Checklist		
Step	**Yes**	**No**
1. Did trainee select the correct panel board needed for their job?		
2. Did trainee leave air circulation space behind panels installed din wet locations?		
3. Did trainee block and tag feeder panels feeding the panel that they are working on?		
4. Did trainee know how to select protective devices for the job they are working on?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

INSTALL

MODULE 18 **AFQTP UNIT 1**

BRANCH CIRCUITS (18.1.6.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

BRANCH CIRCUITS

Task Training Guide

STS Reference Number/Title:	18.1.6. - Distribution systems, 600 volts and less, install branch circuits
Training References:	• CDC 3E051 A Vol. 4 • National Electrical Code, Article 210, Branch-Circuit
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• Fish tape • Electrical tape • General tool kit • Approved lubricant
Learning Objective:	• Given equipment, install branch circuits
Samples of Behavior:	• Follow approved methods to install branch circuits • Know safety requirements associated with installing branch circuits
Notes:	
• Any safety violation is an automatic failure.	

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

BRANCH CIRCUITS

Background: Electrical circuits installed in a building are either branch circuits or feeder circuits. Branch circuits run between the final overcurrent devices and the outlets to connect electrically operated equipment. Small buildings usually have one main distribution panel board to which the branch circuits are connected.

Larger buildings require more than one panel board to meet their power needs. Although the main panel board may be used for both branch circuits and feeder circuits, it is usually limited to feeder circuits. A separate panel board (located near the main panel board) to feed nearby branch circuits is normally preferred. In some cases, a panel board at the end of a feeder circuit becomes a junction point to which sub-feeders are attached. These sub-feeders, in turn, supply branch circuit panel boards. Consequently, through the installation of feeder circuits, it is possible to use a single set of large conductors to replace several long small conductors that are required when all branch circuits connect to the main entrance panel board. Feeder circuits allow panel boards to be located so that the wiring needed for branch circuits is greatly reduced. Generally, such circuit arrangements reduce voltage loss in the conductors and save material and labor.

NOTE:
Feeders are the wires that connect panels and sub-panels. Branch circuits are the wires that connect equipment to the protective devices in a panel.

Branch circuits may be installed by any method approved by the *NEC®* for the installation of electrical circuits. The main objective is that circuits are installed to keep troubles and hazards at a minimum, consistent with existing conditions. Usually, you use nonmetallic cable for circuits that are not subject to damage or excessive dampness.

To perform the tasks, follow these steps:

SAFETY:
WHEN PERFORMING ANY ELECTRICAL WORK ALWAYS WEAR EYE PROTECTION WHEN NECESSARY. WHEN USING STEPLADDERS, DON'T STAND ON THE TOP STEP OF THE LADDER. DON'T USE THE LADDERS AS A WORKBENCH. ALWAYS BE ALERT AT ALL TIMES WHEN WORKING AROUND LIVE ELECTRICAL CIRCUITS OR PARTS.

NOTE:
While nearly all types of wire may be used in conduit installations, the most common types used are those made with thermoplastic insulation. No matter what type of wire is installed always be sure to pull in enough for the job. Be sure to leave at least six inches in boxes for splicing and plenty in the panel for connections.

Step 1: Pulling Conductors.
- For short conduit runs with few wires, the conductors can be pushed through the conduit from one box to the next.
- When the conduit has several bends it may be necessary to use a fish tape to pull the wires through the conduit.
- The fish tape normally has a hook on one end, which is pushed through the conduit.
- The hook makes it easier to push the tape through and provides a method of attaching the conductors for pulling.

- Once you have the fish tape in the conduit, attach the hook to the wires to be pulled, as shown in Figure 1 below.

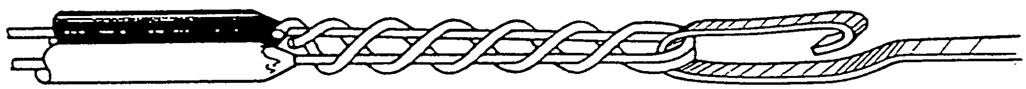

Figure 1, Wires attached to fish tape

- Remove 4 to 6 inches of the insulation from the ends of the wires.
- Thread them through the hook in opposite directions; bend them back and twist them around each other.
- Then tape the hook and bare conductors to strengthen the attachment and make pulling easier.
- Use just enough tape to cover the hook and wires.

NOTE:
Wire pulling usually takes two people, one to pull the fish tape, the other to feed the conductors into the conduit. The fish tape should be fed into the conduit end from which it is easiest to pull.

SAFETY:
WHENEVER CONDUCTORS ARE BEING PULLED INTO ENERGIZED PANEL, BE CAREFUL TO KEEP CLEAR OF THE BUSBARS, AND PULL CONDUCTORS FROM THE PANEL TO THE FIRST JUNCTION BOX. ALL ENERGIZED PARTS SHOULD BE COVERED WITH A RUBBER BLANKET.

- When several conductors must be fed into a conduit, you should keep them parallel and straight and free from kinks and bends.
- Wires that are allowed to cross each other form a bulge and are hard to pull around bends.
- Whenever possible, feed conductors downward; e.g., from the second floor to the first, so the weight of the wires will help in the pulling process.
- Another way to ease the pulling of conductors is to rub an approved lubricant, such as soap, talc, soapstone, or other non corrosive substance, onto the insulation or blow it into the conduit.
- You may find that it is hard to keep the fish tape from slipping in your hands when pulling long runs with several bends.
- When this is a problem, the back side (insulation crushing point) of a pair of lineman's pliers may be used to grip the tape to give you a good pulling handle.

NOTE:
Remember, at least 6 inches of free conductor must be left at each outlet to make up splices or to connect devices. Conductors which are not spliced or connected to a device can be pulled directly through the box.

- Once you have installed the conductors Ohm the cable to ensure no opens, shorts or grounds were incurred in the pulling process.

> **SAFETY:**
> **AS GOOD PRACTICE ALWAYS BEGIN YOUR CONNECTIONS AT THE EQUIPMENT YOU ARE FEEDING AND WORK BACK TOWARDS YOUR SOURCE. THIS WILL PREVENT ACCIDENTAL ENERGIZING OF THE CIRCUIT YOU ARE WORKING ON.**

Step 2: Install devices, switches, receptacles, or fixtures.

- After the cable has been tested, and all other work is complete, you are ready to install the devices, switches, receptacles, and lighting fixtures.

Review Questions
for
Branch Circuits

Question	Answer
1. Branch circuits might be described as those that deliver power to the final overcurrent devices.	a. True b. False
2. The ______ is used to strengthen the pulling of conductor.	a. Fish tape b. Basket grip c. Tape d. Wire ties
3. Whenever pulling conductor into energized panels, always _________.	a. De-energize. b. Cover with rubber blankets. c. Wear rubber gloves. d. All of the above.
4. At least ____ inches of conductors must be left at outlet to make up splices and connect devices.	a. 4 b. 6 c. 8 d. 10
5. Conductors are installed upward: e.g., from first floor to the second so the weight of the wires help in the pulling process.	a. True b. False

BRANCH CIRCUITS

Performance Checklist		
Step	**Yes**	**No**
1. Did Trainee leave at least 6 inches of wire in boxes for splicing ?		
2. Did trainee feed conductors downward so that the weight would help in the pulling process?		
3. Did trainee ohm conductors to ensure that no opens, shorts, or grounds existed after pulling cables?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

INSTALL

MODULE 18 **AFQTP UNIT 1**

CONDUIT (18.1.9.3.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

CONDUIT

Task Training Guide

STS Reference Number/Title:	18.1.9.3. - Distribution systems, 600 volts and less, install circuit extensions using conduit
Training References:	• CDC 3E051A, Vol. 4 • National Electrical Code
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool kit • Conduit straps • Conduit bodies
Learning Objective:	• Given equipment, install conduit circuit extensions
Samples of Behavior:	• Following approved methods, install conduit circuit extension • Know safety requirements associated with installing conduit circuit extensions
Notes:	
• Any safety violation is an automatic failure.	

CONDUIT

Background: Building designers and electrical planners try to anticipate future electrical needs of occupants prior to construction of a building. Changes in the use of the building, new equipment, or rearranging of the walls may call for additions to existing circuits. These additions are called circuit extensions.

A circuit extension, as the name implies, is used to extend an existing circuit. The extension must be a continuous unbroken length of the assembly with no splices or exposed conductors between fittings. Each run must terminate in a fitting that covers the end of the assembly. One or more extensions can be run in any direction from an existing outlet, but not on the floor or within 2 inches from the floor.

Electrical metallic tubing (EMT) is described in NEC Article 348. Installation of EMT should meet the requirements in Article 300. EMT CAN NOT be used where it might be subjected to severe physical damage, where its protection from corrosion is solely enamel, in cinder fill where subject to moisture unless protected as specified in the NEC, or in hazardous locations except under certain conditions. EMT is not threaded, however, where integral couplings are used, the couplings can be factory threaded. All couplings and connectors used should be made tight.

Before you can install extensions, you must find out if the circuit you are extending has the capacity for the extra load. You can determine this by subtracting the present connected load from the fused capacity of the circuit. If all of the outlets on the existing circuit do not have connected loads, you should use their average load to obtain the connected-load figure. When you know for sure that the existing circuit has the capacity, you can add the extension.

To perform the tasks, follow these steps:

Step 1: Preparation for extension.

- Determine if the circuit you are extending has the capacity for the extra load.
- Determine if the installed conduit box will support extension. If not install one that will.
- De-energize the circuit that the extension will be added to.

Step 2: Installation of extension.

- Measure the length of conduit needed for the extension and bend as needed.
- Bends should be made so that the tubing is not damaged and the internal diameter of the tubing is not reduced. Refer to NEC Table 346-10 for the radius of curve.

> **NOTE:**
> In one run of EMT, there can not be more than the equivalent of four-quarter bends (360° total). One run is between pull points such as conduit boxes.

- Ream or finish all cut ends of EMT. This is required to remove rough edges.
- Support conduit by straps or hangers throughout the entire run.
- On a wooden surface, you can use nails or wood screws to secure the straps.
- On brick or concrete surfaces, you must first make a hole with a star or carbide drill and then install an expansion anchor.
- Use an expansion tool to force the anchors apart, forming a wedge to hold the anchor in the hole. Then, secure the strap to the surface with machine screws attached to the anchor.

- On tile or other hollow material, secure the straps with toggle bolts.
- If the installation is made on metal surfaces, drill holes to secure straps or hangers with machine or sheet-metal screws.
- Holes or notches in framing members may serve as supports.

NOTE:
EMT and IMC require supports within 3 feet of each outlet box, junction box, cabinet, or fitting, and every 10 feet thereafter. Also, you must support rigid metal conduit within 3 feet of a box. But, the distance between supports may be increased to 20 feet on direct vertical runs of rigid from machine tools and other equipment if threaded couplings are used and the riser is supported at each end.

Step 3: Connection of circuitry.

- To determine the length of wire to be pulled, simply add the lengths of conduit, the size and number of boxes to go into or through, the length of wire to leave in the boxes, and the makeup at the distribution panel.
- A bare wire provides an equipment ground at the outlet boxes.
- If metal boxes are used, the equipment-grounding conductor must be fastened to the box using either a grounding clip (Figure 1) or a grounding screw (Figure 2).

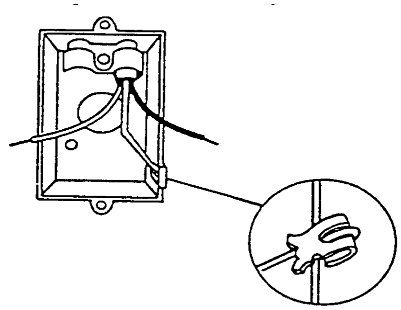

Figure 1, Grounding Clip

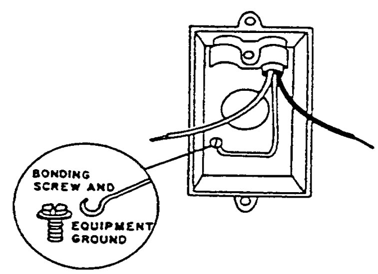

Figure 2, Grounding Screw

SAFETY:
A SCREW USED FOR GROUNDING PURPOSES MUST NOT BE USED FOR ANY OTHER PURPOSE.

- When the grounding clip is used, the grounding wire is slipped through the clip and then the clip is forced onto the edge of the box.
- The grounded duplex receptacle comes equipped with a green hex head screw to be used for connecting the grounding wire.
- When more than one receptacle is connected in a circuit, the NEC requires that these receptacles be connected to the grounding wire in such a way that the continuity of the circuit equipment ground is not broken if the receptacle is removed.

NOTE:
Figure 3 shows how the equipment ground must be connected to the receptacle when there is more than one outlet in the circuit. Notice in the figure, that if you were to remove the receptacles, the grounding circuit would still be complete. Figure 4 shows an example of how a single receptacle in a circuit can be grounded using a grounding clip. Grounding the receptacle in this way bonds the box, grounding wire and receptacle, and precludes use of an additional jumper wire.

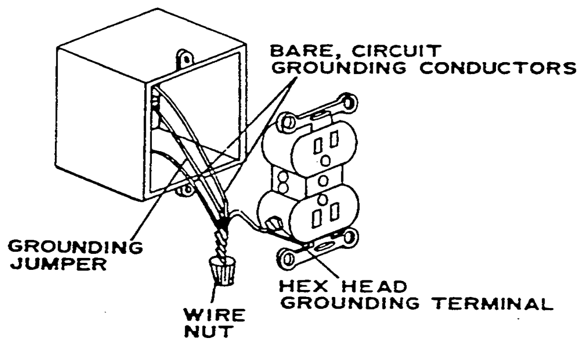

Figure 3, Device Grounding (more than one receptacle in circuit)

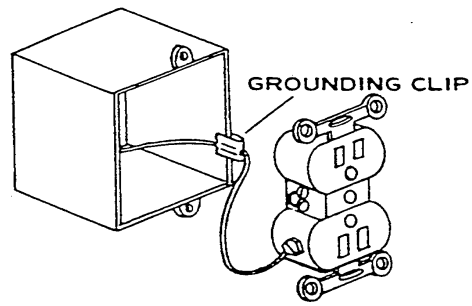

Figure 4, Single Receptacle (grounding using a grounding clip)

Review Questions
for
Conduit

Question	Answer
1. One or more extensions can be run in any direction from an existing outlet, but not on the ______ or within __ inches from the floor.	a. Ceiling , 2 b. Ceiling, 4 c. Floor, 2 d. Floor, 4
2. Before you can install extensions, you must find out if the circuit you are extending has the ________.	a. Proper Amperage rating. b. Capacity for the extra load. c. Insulation value needed. d. None of the above.
3. If all of the outlets on the existing circuit do not have connected loads, you should use _______ to obtain the connected-load figure.	a. Their total load b. Their average load c. Half the total load d. Half the average load
4. Holes or notches in framing members may serve as supports.	a. True b. False
5. Rigid metal conduit must be supported within ____ feet of a junction box.	a. 2 b. 3 c. 4 d. 5
6. What connects equipment-grounding conductors to junction boxes?	a. Grounding flanges b. Grounding strap c. Grounding lugs d. Grounding clips
7. When more than one receptacle is connected in a circuit, it as not necessary that the continuity of the circuit remains if a receptacle is removed from the circuit.	a. True b. False

CONDUIT

Performance Checklist		
Step	**Yes**	**No**
1. Did the trainee determine if the circuit had the capability to handle the extension?		
2. Did the trainee ensure that no more than 360 degrees of bend was placed in one run of conduit?		
3. Did the trainee strap all conduits within 3 feet of all junction boxes?		
4. Did the trainee ground receptacle using grounding clips and screws?		
5. Did the trainee configure the wiring such that if one receptacle was removed, continuity of the circuit remained?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

DISTRIBUTION SYSTEMS, 600 VOLTS AND LESS

MODULE 18 AFQTP UNIT 3

TROUBLESHOOT DISTRIBUTION SYSTEMS (18.1.9.3.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

TROUBLESHOOT DISTRIBUTION SYSTEMS

Task Training Guide

STS Reference Number/Title:	18.3. - Distribution systems, 600 volts and less, troubleshoot distribution systems
Training References:	• CDC 3E051A, Vol. 4
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool box • Multi-meter
Learning Objective:	• Given equipment, troubleshoot a distribution system for opens, shorts, and grounds
Samples of Behavior:	• Follow the required steps to troubleshoot a distribution system for opens, shorts, and grounds • Know safety requirements associated with troubleshooting distribution systems
Notes:	
• Any safety violation will result in automatic failure.	

TROUBLESHOOT DISTRIBUTION SYSTEMS

Background: A majority of your job as an electrical systems specialist will be maintaining and troubleshooting systems that are already installed. Your ability to find a faulty condition in a short period of time can play a vital part in shortening the downtime caused by the failure. To find troubles in a circuit, you must do some inspecting, some calculating, and some instrument testing. A few moments spent studying the circuit diagrams before you actually start troubleshooting will simplify the task of isolating the problem. Use logic when you're troubleshooting. The trial and error method of finding faults is inefficient and time consuming. Troubles in an electrical system can be classified as either open, short, ground, or a combination of these.

An open circuit is one that has no complete path of continuity. A circuit may be intentionally opened by a switch or by disconnecting the circuit at some terminal. A broken switch, blown fuse, loose connection, or a broken conductor may unintentionally open a circuit. An indication that the circuit has an open will be that the unit is not operating (the lamp will not light or the motor will not run). This is the most common type of trouble you will run into.

A short circuit results when two conductors of different potential come in contact with each other, which bypasses a unit of resistance. When this occurs, the protective device in the circuit is normally opened. A short circuit can also occur when two conductors of the same potential come in contact with each other and no resistance is bypassed. This is usually referred to as a shorted control. A good example of this is a switch loop where the two conductors of the loop are touching and bypassing the switch. When this occurs, the device being controlled by the switch will operate continuously.

If the conductor is making contact unintentionally with some metallic part of the wiring system such as the conduit, it is called a ground. This is not to be confused with an intentional ground such as the service entrance switch ground or the bonded conduit system. Grounds or short circuits can be as follows:

- Solid.
- Partial.
- Floating

This situation presents a serious safety hazard, because the machinery may still operate even though it has a short circuit. This is especially true in motors and some appliances. A solid ground or short circuit is one in which a full voltage reading is obtained across the terminals of a blown fuse when the load is disconnected from the circuit. The circuit resistance in this case is very low, and the current is very high so that the fuse will blow. A partial short or ground is one in which the resistance between each of the phase wires or between the phase wire and the ground is partially lowered but still remains high enough to prevent enough current to blow the fuse. Grounds of this type are generally more difficult to locate than are solid grounds. A floating ground is a condition in which the resistance of the defect in a system varies from time to time. Grounds of this type may be present in an electrical system for some time before their existence becomes known.

A floating ground is indicated when fuses continue to blow on the phase side of a circuit and a circuit test shows no defects in the system. In grounds of this type, fuse trouble may not occur for several days. Then the ground recurs, and the fuses are blown again.

To perform the task, follow these steps:

Step 1: Visual check.

- Make a visual inspection and check for the obvious trouble.
- Check for loose connections, loose wires, abraded wires, and loose fittings.

Step 2: Operational check.

- Make an operational check of the circuit if possible.

> **NOTE:**
> If a short or ground exists, protective devices will actuate before the system will operate. Even this fact is useful to you in troubleshooting, as it will more closely identify the type of trouble you are hunting.

Step 3: Analyze the situation.

- Analyze the problem and take systematic steps to locate it. You not only save much time and energy but also will often prevent damage to expensive equipment.

Step 4: Troubleshoot open circuits.

- Turn on the power to the circuit.
- Check the fuse or circuit breaker panel.
- Set the voltmeter to the proper scale.

> **NOTE:**
> If you do not know the value of the incoming voltage, set the meter to the highest scale; then work down to the proper scale.

- Check each incoming phase by connecting one lead of the voltmeter to the neutral and the other to each phase one at a time.

> **NOTE:**
> On a three-phase, 120/208-volt service, you should get 120 volts on each phase to ground. Less than 120 volts on one phase means that phase is open and you are getting a feedback from equipment connected to the load side of the panel.

- Sometimes there will be a slight variation of normal voltage from the different phases. Therefore, to determine whether one phase is de-energized, check between the phases.
- To perform this test, place one lead of the voltmeter on phase A and the second lead on phase B, and read the voltage. It should read approximately 208 or 240, depending upon the system.

- After you have taken this reading, move the second lead to phase C and take the reading.
- After this reading, move the first lead to phase B and take the reading. You have now read between all phases and a lower than normal reading indicates an open phase.

> **NOTE:**
> Which phase is de-energized? Assume that phase B has a blown fuse. When you take your reading between phases A and B (Figure, 1), you get a low-voltage reading. Your next reading, between phases A and C, reads normal, but, the next reading, between phases B and C, again is a low reading. Each time you read to phase B, you get low voltage. This is a good indication that phase B is open.

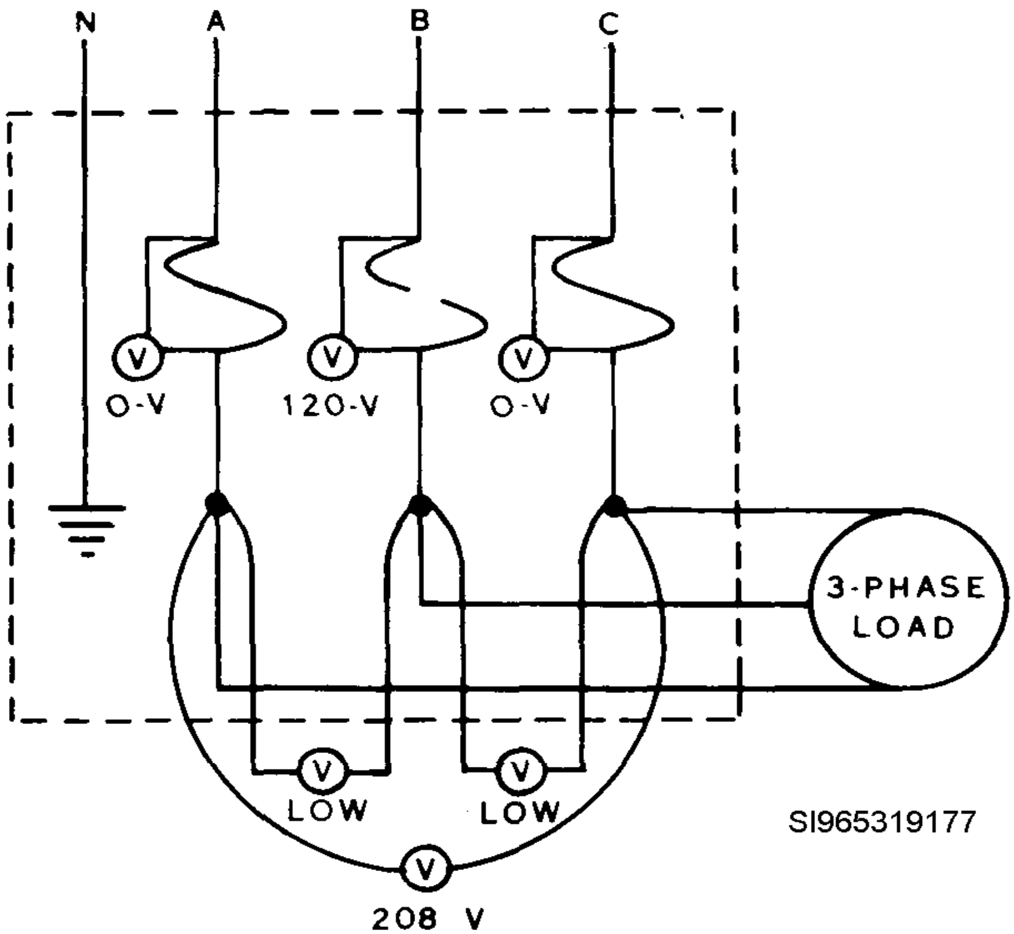

Figure 1, Checking For Blown Fuse On A Three-Phase System

- Another way to determine which phase is open is to place one voltmeter lead on the top of the fuse and the other lead on the bottom of the same fuse. If you get a voltage reading across the fuse, that fuse is open.
- Assuming that everything is all right at the main panel, examine the rest of the circuit.

NOTE:
Illustrations help explain the procedure for locating an open in a circuit. Figure 2 shows a circuit with a lamp in series with a single-throw switch and fuse, and the normal voltage readings at the various points of the circuit.

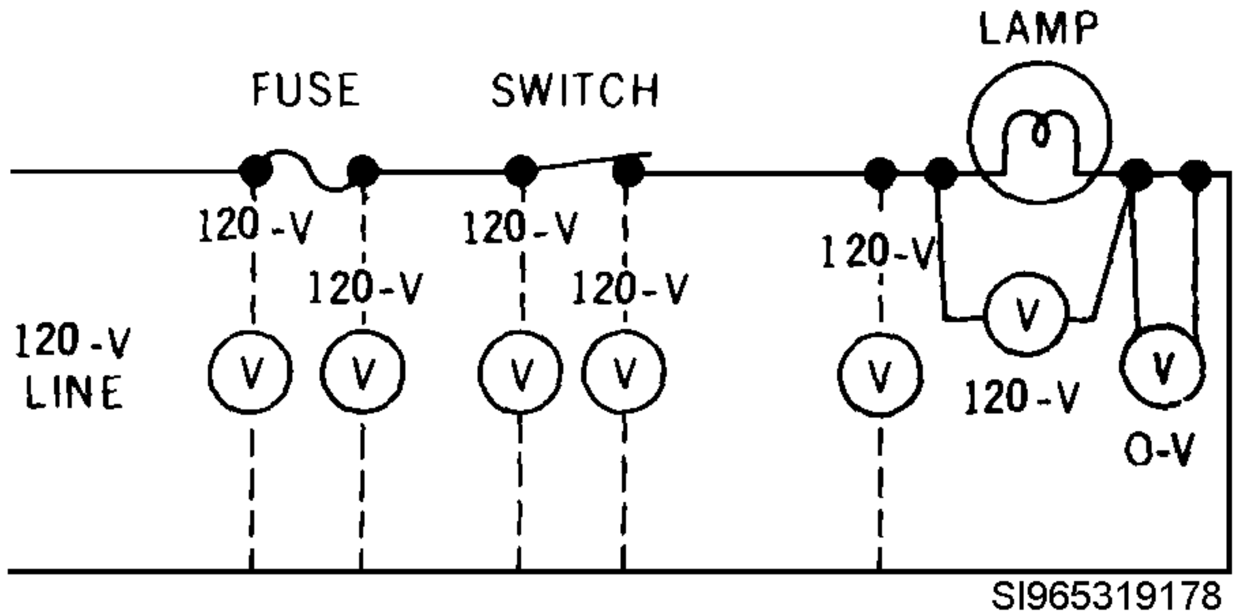

Figure 2, Circuit With Lamp, Switch, And Fuse

- If the lamp fails to light, check the circuit in progressive steps from the last point where voltage is known to be present, through the circuit and lamp.

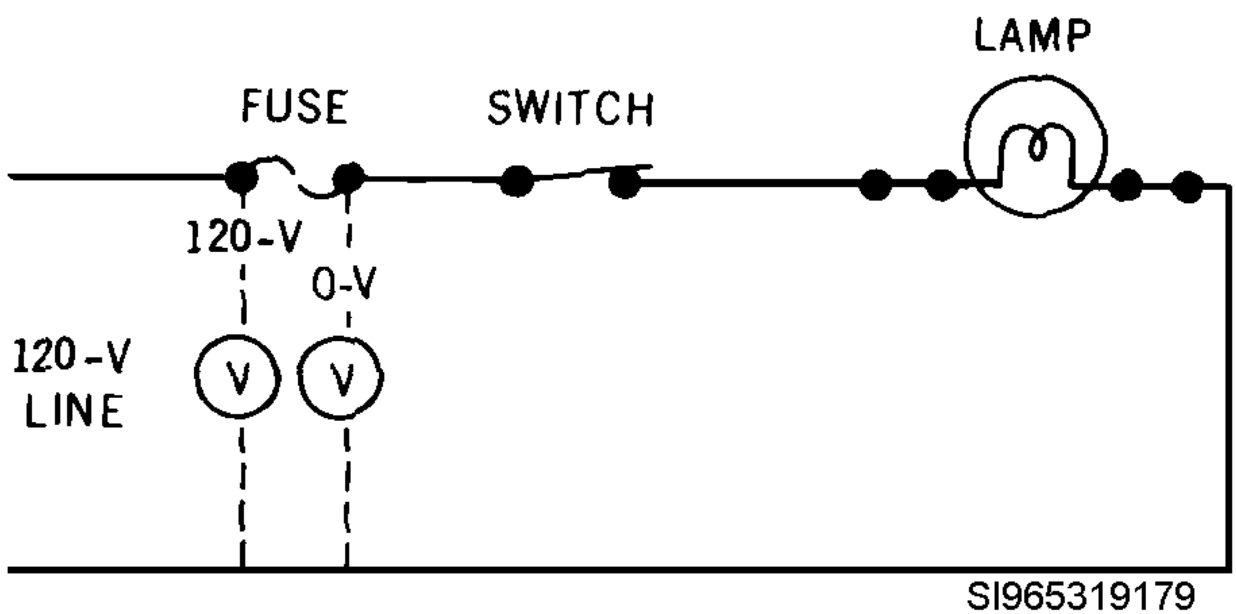

Figure 3, Circuit With Blown Fuse

- In Figure 3, we have voltage at one connection of the fuse and no voltage at the other. Since the fuse is a conducting unit, normally the same voltage reading should occur between both sides of the fuse and the ground. The only conclusion in this case, then, is that the fuse is open.

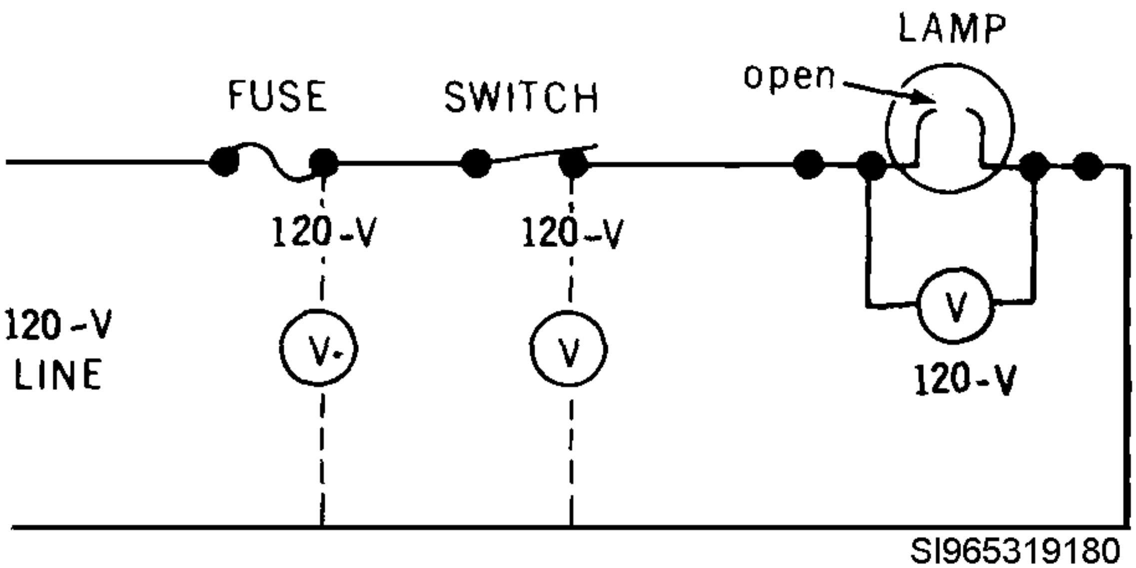

Figure 4, Circuit With Burned-Out Lamp

- Figure 4 shows that there is a voltage reading when the voltmeter is connected across the lamp. The logical assumption is that the lamp is inoperative. To be sure the lamp is inoperative, you must check it with an ohmmeter. Fuses, switches, and lamps are vulnerable; you should check them first in a circuit.

> **SAFETY:**
> **WHEN USING AN OHMMETER, BE SURE THAT THE CIRCUIT IS DE ENERGIZED AND IS ISOLATED TO PREVENT READING RESISTANCE FROM OTHER PORTIONS OF THE CIRCUIT.**

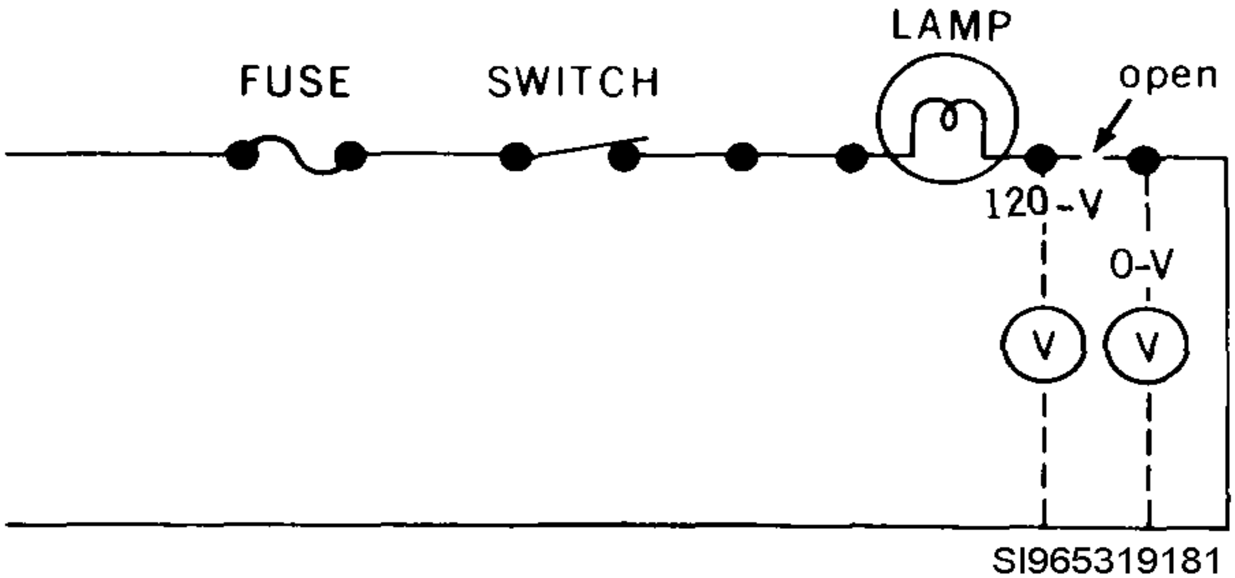

Figure 5, Circuit With An Open

- In Figure 5, the lamp does not light and the voltmeter shows voltage from the ground screw of the lamp to the neutral wire. This indicates an open in the ground wire. When you connect the voltmeter at another point at the right of the lamp and no voltage is indicated, you can assume that there is an open in the wiring between this point and the lamp connection.

Step 5: Troubleshoot Shorts and Grounds.

- First, disconnect all the equipment in the circuit and install a new fuse or place the circuit breaker to the ON position.
- If the short is clear, then the trouble will be found in the equipment. However, if the short circuit does not clear and the fuse burns out again or the circuit breaker trips, then the trouble is in the wiring.
- To find the short in the electrical wiring, you first disconnect the wires at both ends of the circuit and test each wire with an ohmmeter.
- However, for your safety, before you begin testing with the instrument, be sure that the circuit you are about to test is de-energized.
- If there is a short between the wires, a low-resistance reading appears on the ohmmeter. If no short exists between the wires, a high-resistance reading appears on the ohmmeter.
- You should continue this procedure until the short is found.
- Let's assume that a light circuit is faulty. Using Figure 6 as an example, you see a circuit with three lights controlled by a switch with a short at the junction box of the middle lamp.
- Disconnect the wires at the fuse panel to isolate the circuit and to prevent feedback from other circuits.

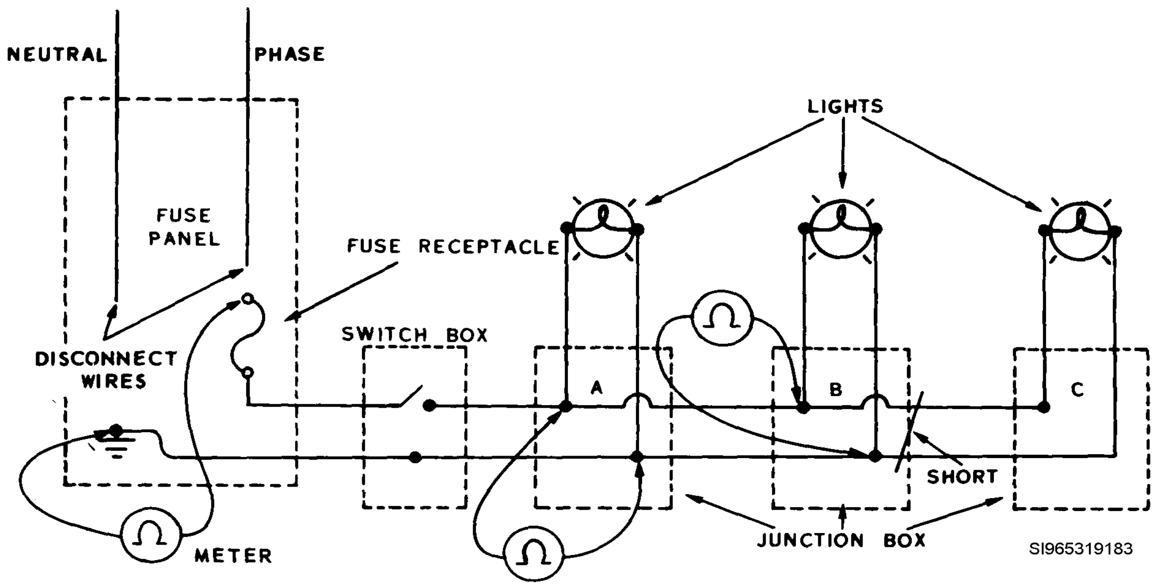

Figure 6, Faulty Lighting Circuit

- Connect one lead of the ohmmeter to the neutral and the other to the wire you have just disconnected. With the switch open, the ohmmeter will read infinity. Closing the switch causes the ohmmeter to read continuity, showing that the short is beyond the switch.
- You can now go to the nearest junction box and test at the first light.
- Remove all light bulbs from the circuit.
- Disconnect point A and connect the ohmmeter between the neutral and the wire leading to the first lamp. You will read infinity.

NOTE:
Remember, infinity means that the circuit is good and continuity means a short.

- Now, connect the ohmmeter between the neutral and the lead going to the middle lamp. The reading will show continuity, indicating the short is beyond point A.
- Leave point A open at this time and continue on to the middle lamp.
- Disconnect point B and take the same readings that you took at the first light. From these tests, you can determine that the circuit between the first and middle lamp is all right (infinity reading), and the trouble must be between the second and third lamp.
- By checking closely at the middle junction box, you can probably see charred or frayed wires indicating the problem.
- You may need to continue your check to point C. Use the same procedure as with the other lamp, and find the trouble between points A and C.

SAFETY:
BE EXTREMELY CAREFUL WHEN WORKING AROUND ENERGIZED LINES. IF YOU DE-ENERGIZE A CIRCUIT, BE SURE TO TAKE THE PROPER ACTIONS TO BLOCK AND TAG THE CIRCUIT WHILE YOU ARE WORKING ON THEM.

Review Questions
for
Troubleshoot Distribution Systems

Question	Answer
1. What types of troubles can be found in a circuit?	a. Shorts b. Grounds c. Opens d. All of the above.
2. A ____circuit is one that has no complete path of continuity.	a. Open b. Closed c. Grounded d. Shorted
3. A ____ circuit results when two conductors of different potential come in contact with each other, bypassing a unit of resistance.	a. Open b. Short c. Grounded d. Distribution
4. If the conductor is making contact unintentionally with some metallic part of the wiring system such as the conduit, it is called a ground.	a. True b. False
5. What should be your first step in troubleshooting a circuit?	a. Operational check b. Visual check c. Analyze problem d. Meter check
6. If you do not know the value of the incoming voltage, set the meter to the ______scale; then work your way to the proper scale.	a. Lowest b. Central c. Highest d. Open
7. When using an ohmmeter, be sure that the circuit is ____?	a. Energized b. Grounded c. De-energized d. Complete
8. What is indicated if, after you disconnect all equipment and install a new fuse, the fuse does not burn out?	a. The fuse was bad. b. The trouble is in the wiring. c. The trouble is in the equipment. d. There is an open circuit.
9. When testing for a short or ground with an ohmmeter, what does a reading of infinity mean?	a. A direct short. b. A good circuit. c. A ground is present. d. There is continuity between the conductors.

TROUBLESHOOT DISTRIBUTION SYSTEMS

Performance Checklist		
Step	**Yes**	**No**
1. Did the trainee perform a visual check?		
2. Did the trainee perform an operational check?		
3. Did the trainee analyze the situation?		
4. Did the trainee disconnect power before using ohmmeter?		
5. Did the trainee properly block and tag circuits while working on them?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

DISTRIBUTION SYSTEMS, 600 VOLTS AND LESS

MODULE 18 **AFQTP UNIT 9**

TROUBLESHOOT FACILITY LIGHTING (18.9.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

TROUBLESHOOT FACILITY LIGHTING

Task Training Guide

STS Reference Number/Title:	18.9. - Distribution systems, 600 volts and less, troubleshoot facility lighting
Training References:	• CDC 3E051A Vol. 4
Prerequisites:	• Possess as a minimum a 3E031 AFSC
Equipment/Tools Required:	• General tool kit • Multimeter
Learning Objective:	• Given equipment, troubleshoot facility lighting
Samples of Behavior:	• Following approved methods, troubleshoot facility lighting • Know safety requirements associated with troubleshooting facility lighting
Notes:	
• Any safety violation is an automatic failure.	

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

TROUBLESHOOT FACILITY LIGHTING

Background: While many meters and other pieces of equipment are available to you for troubleshooting, the most important thing involved is your common sense. To become skilled at troubleshooting, you need to follow a logical sequence of operations.

The multimeter is the most versatile meter you can use when troubleshooting, because it incorporates voltmeter, ohmmeter and ammeter functions. A voltmeter is useful in tracing a circuit to find opens. To do this, you simply energize the circuit and test with the voltmeter at different points along the circuit starting at the power source. At the point where power is no longer measurable, the circuit will most likely have an open.

A continuity tester is a meter or device used to check for a continuous circuit. A continuous circuit is one that has a complete path for current to flow. When doing this type of testing we only want to know if the circuit is complete, the resistance is not important.

An ohmmeter can be used as a continuity tester by checking for a reading of infinity for an open and a small resistance reading for a complete circuit. If an ohmmeter is not available we can design our own continuity tester by simply putting a bell or buzzer in series with a battery power source so that by completing the circuit between two wire leads the light or buzzer will operate. This tester can be placed in the circuit the same way you would with an ohmmeter. Remember that your circuit must be de-energized before placing the ohmmeter or continuity tester for testing.

SAFETY:
TROUBLESHOOTING CAN BE ACCOMPLISHED WITH POWER ON OR OFF. WHEN POWER IS ON, YOU HAVE THE ELECTRIC HAZARD ASSOCIATED WITH WORKING ON ENERGIZED EQUIPMENT. BE ALERT DO NOT GROUND YOURSELF. TURN OFF ELECTRICITY BEFORE REMOVING DEVICES OR WIRE NUTS FROM THEIR CONDUCTORS. MAKE A VISUAL INSPECTION AND CHECK FOR THE OBVIOUS TROUBLE, MANY TIMES THE TROUBLE IS EASILY SEEN. LOOK FOR BROKEN WIRES OR CONNECTORS, LOOSE TERMINALS, SIGNS OF OVERHEATING SUCH AS BLACKENED SPOTS ON EQUIPMENT OR BURNED OR BROKEN INSULATION. CAN YOU SMELL ANY BURNED INSULATION? CAN YOU FEEL ANY OVER HEATED UNITS? DON'T OVERLOOK THE OBVIOUS. IS THE LIGHT BULB BURNED OUT? A GOOD VISUAL INSPECTION WILL SOLVE MANY OF YOUR TROUBLE CALLS.

To perform the task, follow these steps:

Step 1: Operational Check.
- If possible, make an operational check of the circuit.
- If a short or ground exists, protective devices will actuate before the circuit can operate.
- Even this fact is useful to you in troubleshooting, as it will more closely identify the type of trouble you are hunting.

- If the circuit is still not operational check the connections at the switch.
- If no power is reaching the switch there may be a junction box or an open between the switch and the power source, this may be the problem.
- In the event power is reaching the switch and it's operational, proceed to the first light in the circuit.
- If no power is reaching the first light, there may be junction box or an open between the first light and the switch, this may be the problem.
- Depending on the number of lights in the circuit, you may want to divide the circuit in half and apply the same procedure until you locate the problem.

Step 2. Analyze Trouble.

- If these previous steps have not located the trouble, you are going to have to THINK!
- The indications that you have received should tell you what type of trouble you have.
- Lamp won't light? You have an open circuit.
- Lamp burns out as fast as it is turned on--check for improper power.
- Circuit breaker trips as soon as power is applied? This indicates a short or ground.
- Can't turn the lights off? The problem is a shorted control device.
- If a wiring diagram or schematic of the system is available, use it.
- Check to see where the circuit goes and what equipment is tied into the circuit.
- See if there is a common junction box or conduit run where shorted circuits could occur.

Review Questions
for
Troubleshoot Facility Lighting

Question	Answer
1. The multimeter is the most versatile meter you can use when troubleshooting, because it incorporates _______ functions.	a. Voltmeter b. Ohmmeter c. Ammeter d. All of the above
2. If a _____ or _____ exist, protective devices will actuate before the circuit can operate.	a. Short or ground b. Open or Short c. Ground or open d. None of the above
3. What indicates you have an open?	a. Lamp burns out as fast as it is turned on. b. Lamp won't light. c. Circuit breaker trips as soon as the power is applied. d. Can't turn the lights off.
4. What indicates improper voltage?	a. Lamp burns out as fast as it is turned on. b. Lamp won't light. c. Circuit breaker trips as soon as the power is applied. d. Can't turn the lights off.
5. What indicates a short or ground?	a. Lamp burns out as fast as it is turned on. b. Lamp won't light. c. Circuit breaker trips as soon as the power is applied. d. Can't turn the lights off.
6. What indicates a shorted control device?	a. Lamp burns out as fast as it is turned on. b. Lamp won't light. c. Circuit breaker trips as soon as the power is applied. d. Can't turn the lights off.

TROUBLESHOOT FACILITY LIGHTING

Performance Checklist		
Step	**Yes**	**No**
1. Did trainee perform an operational check of the circuit?		
2. Did the trainee analyze the trouble?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

Air Force Civil Engineer

QUALIFICATION TRAINING PACKAGE (QTP)

REVIEW ANSWER KEY

For

ELECTRICAL SYSTEMS

(3E0X1)

MODULE 18

DISTRIBUTION SYSTEMS, 600 VOLTS AND LESS

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

SERVICE-ENTRANCE

(3E0X1-18.1.1.)

Question	Answer
1. What is the purpose of the overhead service-entrance system?	b. To bring power from the service drop to a panel in the building.
2. What does the raceway protect the service conductors from?	c. Both a and b
3. The service head prevents the entrance of _____ into the raceway.	d. Rain
4. When using SE cable, water can be kept out by the use of a service head or by a ____.	a. Gooseneck
5. The service entrance ends at the service mast.	b. False
6. The first requirement for installation of the service entrance is to determine the ____ of the conductors.	d. Type
7. How does the size of service entrance conductors compare to the size of service drop conductors?	c. Entrance conductors are larger size
8. Copper service drop conductors must be no smaller than ______ AWG	b. Wattmeter
9. What seals a hole around SE cable entering an exterior wall?	a. Rubber gasket
10. Some underground services do not have a service-entrance.	a. True

SERVICE EQUIPMENT

(3E0X1-18.1.2.)

Question	Answer
1. Power enters a building through the ______, which forms the main disconnecting means.	b. Service equipment
2. A panel installed in a home will most commonly be what type of panel?	a. Single phase
3. What is the most important consideration when selecting a panel?	c. Voltage and amperage
4. Insulated bushings are required for ungrounded No. ___ and larger conductors.	b. 4
5. Bond the grounding bus bar with the neutral bus bar in all distribution panels.	b. False

SYSTEM AND EQUIPMENT GROUNDS

(3E0X1-18.1.3.)

Question	Answer
1. Where can the grounded (neutral), and the grounding conductor be bonded together	c. On the line side of the service entrance disconnect.
2. What is the minimum size of the copper clad steel ground rod electrode.	a. 5/8 diameter by 8 ft long
3. Water pipe (uncoated) and direct buried in earth for a minimum of 10 feet can be used as a stand alone ground electrode	b. False
4. How deep must a ground rod for facility system ground be driven when no protective covering is provided.	d. level to or slightly below grade
5. If a ground rod cannot be driven vertically because of soil conditions it may be driven at a ___-degree angle from the vertical.	a. 25
6. ½”Galvanized iron pipe cannot be used for a grounding electrode	a. True
7. What is the minimum size copper conductor and burial depth for a ground ring.	c. # 2 AWG 30 inches

FEEDERS

(3E0X1-18.1.4.)

Question	Answer
1. Electrical circuits installed in buildings are _______.	d. A & C
2. The Main objective is that circuits installed keep troubles and hazards to a minimum.	a. True
3. Remove ___ to ___ inches of insulation from wires for connection to the fish tape.	c. 4 – 6
4. Which of the following is an approved lubricant used for pulling of cables?	b. Talc
5. Before connecting panelboards, test for _____.	d. All of the above
6. The first conductor connected is the ___.	b. Ground
7. What conductor must be labeled and identified with orange tape in a Delta system?	b. B phase

DISTRIBUTION PANELS AND PROTECTIVE DEVICES

(3E0X1-18.1.5.)

Question	Answer
1. A ________ serves as a center or point in the electrical system where the power is fed to the branch circuits.	b. Distribution panel
2. What is the purpose of the protective devices in a panel board?	a. Protect the circuit against excessive current flow.
3. Any panel that has *more than* 20 percent of its overcurrent devices rated at 30 amperes or less and has provisions for neutral connections is classified as a lighting and appliance panel.	b. False
4. _____ panel boards distribute power to other panel boards located at various points in a building.	c. Feeder
5. Edison-base fuses may be used in new installations.	b. False
6. What are the two types of cartridge fuses?	d. Knifeblade and ferrule
7. A thermal-type circuit breaker has a bimetallic element within the breaker that responds to ___________ change.	c. Temperature
8. Cabinets installed in damp locations must have at least __ inch airspace behind the cabinet to allow for air circulation.	a. ¼
9. Always bond the equipment ground bus bar and the neutral bus in the panel.	b. False

BRANCH CIRCUITS

(3E0X1-18.1.6.)

Question	Answer
1. Branch circuits might be described as those that deliver power to the final overcurrent devices.	b. False
2. The ______ is used to strengthen the pulling of conductor.	c. Tape
3. Whenever pulling conductor into energized panels, always _________.	b. Cover with rubber blankets.
4. At least ____ inches of conductors must be left at outlet to make up splices and connect devices.	b. 6
5. Conductors are installed upward: e.g., from first floor to the second so the weight of the wires help in the pulling process.	b. False

CONDUIT

(3E0X1-18.1.9.3.)

Question	Answer
1. One or more extensions can be run in any direction from an existing outlet, but not on the ______ or within __ inches from the floor.	c. Floor, 2
2. Before you can install extensions, you must find out if the circuit you are extending has the ________.	b. Capacity for the extra load.
3. If all of the outlets on the existing circuit do not have connected loads, you should use _______ to obtain the connected-load figure.	b. Their average load
4. Holes or notches in framing members may serve as supports.	a. True
5. Rigid metal conduit must be supported within ____ feet of a junction box.	b. 3
6. What connects equipment-grounding conductors to junction boxes?	d. Grounding clips
7. When more than one receptacle is connected in a circuit, it as not necessary that the continuity of the circuit remains if a receptacle is removed from the circuit.	b. False

TROUBLESHOOT DISTRIBUTION SYSTEMS

(3E0X1-18.3.)

Question	Answer
1. What types of troubles can be found in a circuit?	d. All of the above.
2. A ____circuit is one that has no complete path of continuity.	a. Open
3. A ____ circuit results when two conductors of different potential come in contact with each other, bypassing a unit of resistance.	b. Short
4. If the conductor is making contact unintentionally with some metallic part of the wiring system such as the conduit, it is called a ground.	a. True
5. What should be your first step in troubleshooting a circuit?	b. Visual check
6. If you do not know the value of the incoming voltage, set the meter to the ______scale; then work your way to the proper scale.	c. Highest
7. When using an ohmmeter, be sure that the circuit is ____?	c. De-energized
8. What is indicated if, after you disconnect all equipment and install a new fuse, the fuse does not burn out?	c. The trouble is in the equipment.
9. When testing for a short or ground with an ohmmeter, what does a reading of infinity mean?	b. A good circuit

TROUBLESHOOT FACILITY LIGHTING

(3E0X1-18.9.)

Question	Answer
1. The multimeter is the most versatile meter you can use when troubleshooting, because it incorporates _______ functions.	d. All of the above
2. If a _____ or _____ exist, protective devices will actuate before the circuit can operate.	a. Short or ground
3. What indicates you have an open?	b. Lamp won’t light.
4. What indicates improper voltage?	a. Lamp burns out as fast as it is turned on.
5. What indicates a short or ground?	c. Circuit breaker trips as soon as the power is applied.
6. What indicates a shorted control device?	d. Can’t turn the lights off.